GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[X] ORIGINAL [ ] REVISION NO. ______

Project No./(Center No.) E-20-653 (R6253-0A0) GTRC/~~GIT~~ DATE 1 / 26 / 87

Project Director: C. S. Martin School/~~Lab~~ CE

Sponsor: Georgia Power Company

Agreement No.: Research Project Agreement dated 12/30/86 (Ref. P.O. #TUHA-00011)

Award Period: From 12/30/86 To 12/31/87 (Performance) 9/15/87 Reports

Sponsor Amount: New With This Change / Total to Date

Contract Value: $ ______ $ 49,876

Funded: $ ______ $ 49,876

Cost Sharing No./(Center No.) ______ Cost Sharing: $ ______

Title: Hydraulic Model Studies of North Georgia Dams

ADMINISTRATIVE DATA

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Military Security Classification: ______
(or) Company/Industrial Proprietary: ______

ONR Resident Rep. is ACO: ______ Yes X No
Defense Priority Rating: ______

RESTRICTIONS

See Attached ______ Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval — Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with sponsor, however none proposed.

COMMENTS:

COPIES TO: SPONSOR'S I.D. NO. 02.256.000.87.005

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Research Communications

GTRC
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SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 6/2/88

roject No. E-20-653 School/~~Lab~~ CE

ncludes Subproject No.(s) N/A

roject Director(s) C. S. Martin GTRC/~~GIT~~

ponsor Georgia Power Company

tle Hydraulic Model Studies of North Georgia Dams

ffective Completion Date: 12/31/87 (Performance) 12/31/87 (Reports)

rant/Contract Closeout Actions Remaining:

- [ ] None
- [x] Final Invoice or Copy of Last Invoice Serving as Final
- [ ] Release and Assignment
- [x] Final Report of Inventions and/or Subcontract: Patent and Subcontract Questionnaire sent to Project Director [x]
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other ____

ntinues Project No. ____ Continued by Project No. ____

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E-20-653

Final Report

HYDRAULIC MODEL INVESTIGATIONS FOR NORTH GEORGIA PROJECT

By
C. Samuel Martin

Prepared for
Georgia Power Company
Atlanta, Georgia

February, 1988

GEORGIA INSTITUTE OF TECHNOLOGY
A UNIT OF THE UNIVERSITY SYSTEM OF GEORGIA
SCHOOL OF CIVIL ENGINEERING
ATLANTA, GEORGIA 30332

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School of Civil Engineering

Georgia Institute of Technology

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FOREWORD

A hydraulic model study of four dams and spillways in North Georgia was conducted for the Georgia Power Company by the School of Civil Engineering of the Georgia Institute of Technology. The investigations were performed under the supervision of Professor C. S. Martin in the Hydraulics Laboratory of the Georgia Institute of Technology.

The four models were constructed in the Shop of the School of Civil Engineering by Mr. Odis Tucker and Mr. Mingt Thein. The calibration of flow meters and the collection of model data were conducted by Mr. Juan Lince and Mr. Mingt Thein under the supervision of Professor Martin.

The assistance and advice given by Mr. Alan Murray of the Georgia Power Company in the course of the investigation is gratefully acknowledged.

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ABSTRACT

Hydraulic model investigations were conducted for four Georgia Power Company Dams and Spillways located in North Georgia. The purpose of the studies was the determination of the rating curves of the spillways and non-overflow sections as well for the condition of a severe flood. The investigations were undertaken as part of a re-licensing procedure required by the Federal Energy Regulatory Commission. Of particular interest was the ability of the entire structures, consisting of the overflow (spillway) sections and the dam crests. For three of the structures the effect of a roadway above the spillways was also determined.

Comprehensive models comprising the entire dam, power house intake structure and other appurtenances, spillway, and upstream topography were constructed for Burton and Nacoochee Dams. The wider Burton Dam Model was constructed at a scale ratio of 80:1, while the narrower Nacoochee Dam Model was built at a scale ratio of 40:1. The Burton Model was tested with and without its bridge above the spillway in place, indicating only a minor effect of the bridge on the total capacity of the dam to pass water. For the Nacoochee Model it was demonstrated that the effect of the upstream bed topography on the overall flow capacity was minor.

Sectional models were built for the Tallulah Falls and Tugalo Spillways, including the bridges. Each model consisted of three spillway bays, with the scale ratios being 32 and 37.5 for the Tallulah Falls and Tugalo Models, respectively. The bridge above the Tallulah Falls Spillway, being quite deep, had a significant effect on the flow capacity of the structure. For the Tugalo Model the effect of the smaller bridge on the discharge capacity of the spillway was, on the other hand, much less. Because of limitations of the 3-ft height of the flume used to test the Tugalo Spillway, the initial model was cut off at its base, making the model shorter than it should be to scale. Subsequent tests conducted by raising the sidewalls of the flume yielded essentially the same results as the shorter model.

The model results for Burton and Nacoochee Dams with the spillways blocked correlated well with published results for broad-crested weirs, indicating that the scale effects for the small Burton Dam were insignificant. The results for the Burton, Tallulah Falls, and Tugalo Spillways also showed similar correlations with those of a broad-crested weir.

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INTRODUCTION

The Georgia Power Company is in the process of filing for re-licensing of six dams at the North Georgia Project (FERC No. 2354). For the Probable Maximum Flood (PMF) for each dam site the corresponding reservoir elevations are needed in order to conduct structural stability analyses. Because of the unusual crest shape of most of the spillways and the fact that water would go over bridges and other non-overflow sections of the dam at the PMF, model studies were recommended to improve the accuracy of the analyses. Of the six dam sites in question -- Burton, Nacoochee, Mathis, Tallulah Falls, Tugalo, and Yonah (listed in the downriver direction) -- only four were model tested. Hydraulic model studies were conducted for dams Burton, Nacoochee, Tallulah Falls, and Tugalo for the purpose of obtaining flow rate -- reservoir level relationships (rating curves) up to and sometimes beyond the predicted PMF.

The four hydraulic model studies were performed in the Old Hydraulics Laboratory of the School of Civil Engineering of the Georgia Institute of Technology. For the Burton and Nacoochee dams the entire dam, spillway, and appurtenant structures such as bridges and power house extensions were included as part of the model. The models were placed in a 14-ft wide channel such that the approach topography could also be included. Because of space and flow limitations as well as the desire to obtain more detailed information regarding bridge interaction with the flow, models for dams Tugalo and Tallulah Falls were built as sectional models of three spillway bays and tested in a 3-ft wide flume.

In this report the consideration of model selection, model limitations, and the final choice of model scale will be initially discussed. For each model a description of the construction methods, the testing procedures and the results will be presented. The uncertainty of the results with respect to model scaling and measurement accuracy will also be addressed. Rating curves for each dam will be presented as well as the variation of the flow coefficient C with reservoir elevation (head). Finally, a comparison of spillway performances will be made in terms of the coefficient C. For the sectional models of the Tallulah Falls and Tugalo Dams the variation of an orifice-type discharge coefficient is reported for the situation for which flow is impacting the bridges.

HYDRAULIC MODELING

Spillway performance represented either in terms of a rating curve or a variation of the flow coefficient C with flow rate (or head) is quite well predictable for standard shapes such as ogees. Variances from the standard occur as a result of unusual approach conditions, presence of piers, gates, bridges and other appurtenances. Indeed, there are little if any results for combined flows over both the overflow (spillway) and non-overflow (dam) sections of the structure. Sectionally, however, the non-overflow dam section can often be treated as a limiting case of a broad-crested weir, for which much literature is available. On the other hand, however, there is very little information available regarding the effect on flow of a bridge directly above a spillway. Except for the Nacoochee dam, of which the Yonah dam is very similar, the spillways of the dams are quite unusual and actually not well shaped as regards flow capacity. Clearly, all of the above variations from a standard spillway crest--unusual crest shape, topography, presence of piers, bridges and other structural appurtenances necessitated the model investigations.

Once a hydraulic model study is commissioned, both the model size and configuration must be chosen with care. The size and water flow capacity of the laboratory together dictate the scale of the model which, expressed as a ratio of prototype to model size, should be as small as practically possible. Comprehensive models which may include more detail such as other structural appurtenances will generally be at a much larger scale (smaller model dimensions). The necessary larger scale ratio of comprehensive models means that some of the flow detail is lost due to small flow passages and resulting undesirable scale effects. Sectional models, on the other hand, yield very good results for the section in question. Obviously, compromises are made in either instance whether comprehensive or sectional models are chosen. Whenever feasible both sectional and comprehensive models should be built in cases where both global and local effects are important.

For spillway and overflow investigations the Froude Law is by far the most important in the field as the effects of viscosity and surface tension are negligible. The hydraulic model should be designed such that the effects of viscosity and surface tension do not affect the results. This is accomplished by choosing a model scale as small as possible. The Froude Law, which relates gravitational and inertial forces yields the following expressions for length ratios and flowrate ratios between prototype and model:

Scale Ratio: $L_R = L_P/L_M$

Head Ratio: $H_P = H_M L_R$

Flow Ratio: $Q_P = Q_M L_R^{2.5}$

MODELS

Considering all of the factors discussed above comprehensive models were built and tested for Burton and Nacoochee sites, while sectional models were utilized for Tallulah Falls and Tugalo Dams. The models for Burton and Nacoochee Dams were built at model scales of 80 and 40, respectively, and tested in the 14-ft flume in the Old Hydraulics Laboratory. The Burton model was constructed of wood and plywood, whereas the Nacoochee model was made exclusively of Plexiglass in order to insure better control of tolerances. Three-bay sectional Plexiglass models were made for Tallulah Falls and Tugalo Dam spillway sections at model scales of 32 and 37.5, respectively. The latter two models were placed in the 3-ft wide glass-walled flume in the Old Hydraulics Laboratory. Due to flow limitations the flume was narrowed to 2-ft to accommodate three bays for the Tugalo model. Some of the geometric features of the four dams are listed in TABLE I.

TABLE I

GEOMETRIC FEATURES OF NORTH GEORGIA PROJECT DAMS

DAM	SCALE	BAYS	PIERS	CREST	LENGTH	LENGTH w/o PIERS
Burton	80	8	7	1860.0	197	176
Nacoochee	40	1	None	1752.5	140	140
Tallulah	32	10	9	1493.0	320	280
Tugalo	37.5	14	13	885.0	357	308

For each test facility a circulating system consisted of a sump, pumps, constant-head tank, distributing pipes with flow-control valves and flow meters, and the respective flume. The flow measuring devices used in the 14-ft flume were of the differential-pressure type -- a Venturi meter and an orifice, depending upon the flowrate range in question. Both of these flow meters were calibrated in a large weighing tank in the same laboratory. The weighing tank, situated directly below the 3-ft wide flume in which the Tallulah Falls and Tugalo models were placed, was the sole measuring device for all tests conducted for those models. For all four model investigations a hook gage connected to an upstream piezometer tapped into the lower portion of the side wall of the respective reservoir was used to determine the stage (reservoir elevation). The scale on the hook gage stand, which could be read to 0.001 ft (model), was carefully referenced to the elevation of the spillway crest using a level.

BURTON DAM

For the intended purpose of including the effects of topography, the bridge over the spillway, and the non-overflow dam section, a comprehensive model was constructed for Burton Dam in the 14-ft wide flume. The 1/80th scale model of the 1040-ft wide dam was placed in a 13.0-ft wide section of the 14-ft flume by installing temporary side walls on the facility. The floor of the flume corresponded to elevation 1752.0 ft, a level near that of the heel of the dam at mid-section. The elevation of the top of the bridge and the top of the non-overflow section (dam crest) was 1873.0 ft, 13.0 ft above the crest of the spillway (1860.0 ft).

The rating curve in terms of reservoir elevation versus prototype discharge is presented on Figure 1 for Burton Dam. The 28 data points were obtained exclusively using the orifice meter because of the relative low model flow for Burton Dam. It was noted that the water initially impinged on the lower part of the bridge above the spillway at a reservoir elevation of 1873.1 ft, corresponding to a discharge of 29,000 cfs. The effect of removing the bridge, which does not offer much flow resistance relative to the entire structure's capacity, is shown by the additional set of data points on Figure 1.

Tests were also conducted to determine the flow characteristics of the non-overflow section of the dam itself by physically placing a vertical barrier behind the spillway. For flow over the 843-ft dam crest alone the rating curve is presented on Figure 2.

The interpretation of these data shown in Figures 1 and 2, as well as later sets for the other models, will be discussed later relative to model scaling effects and other uncertainties.

NACOOCHEE DAM

A comprehensive model was constructed for Nacoochee Spillway and Dam because of the possible effect of the powerhouse extension upstream of the dam on the flow, and the fact that a scale ratio

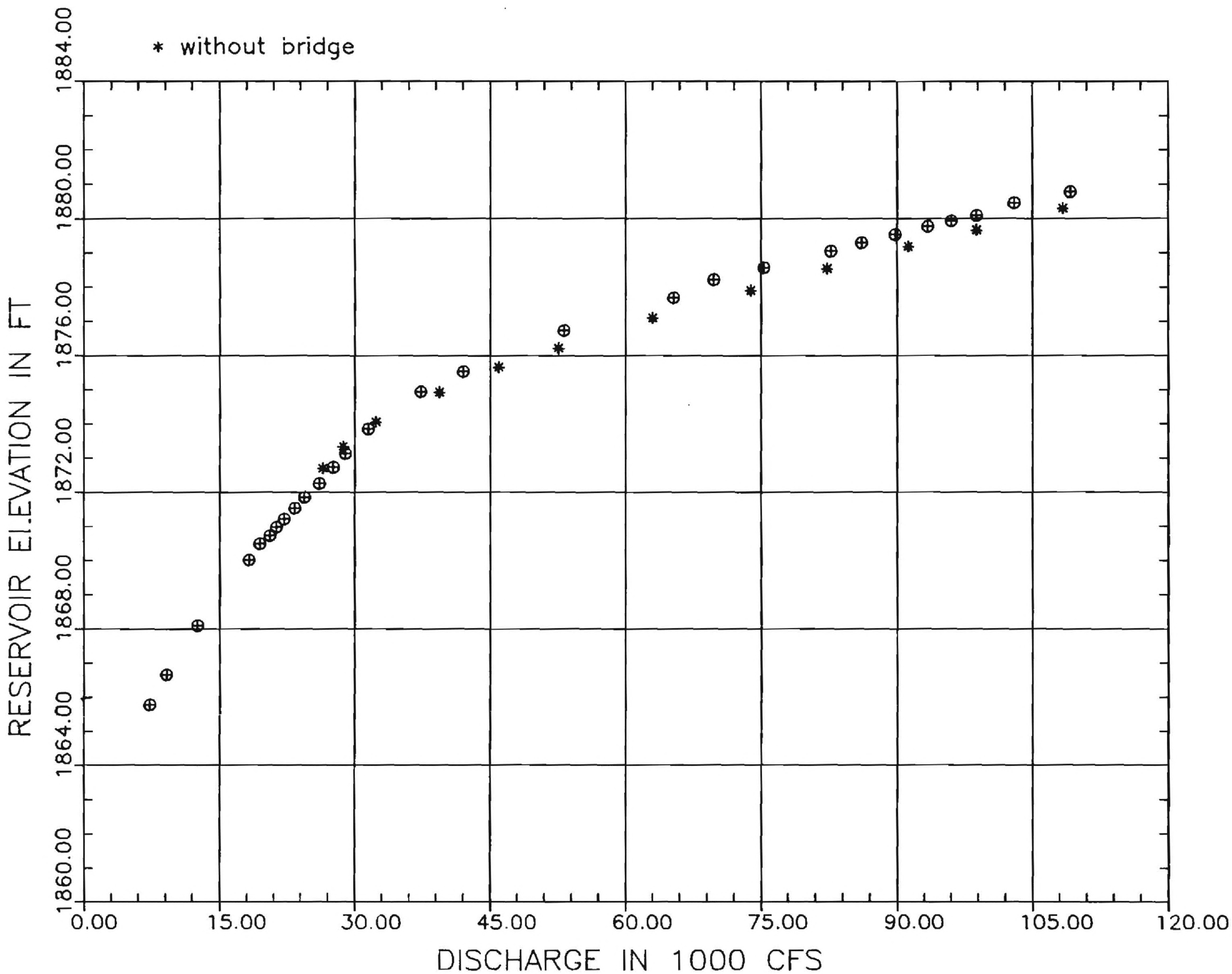


Figure 1. Rating curve for Burton Spillway and Dam

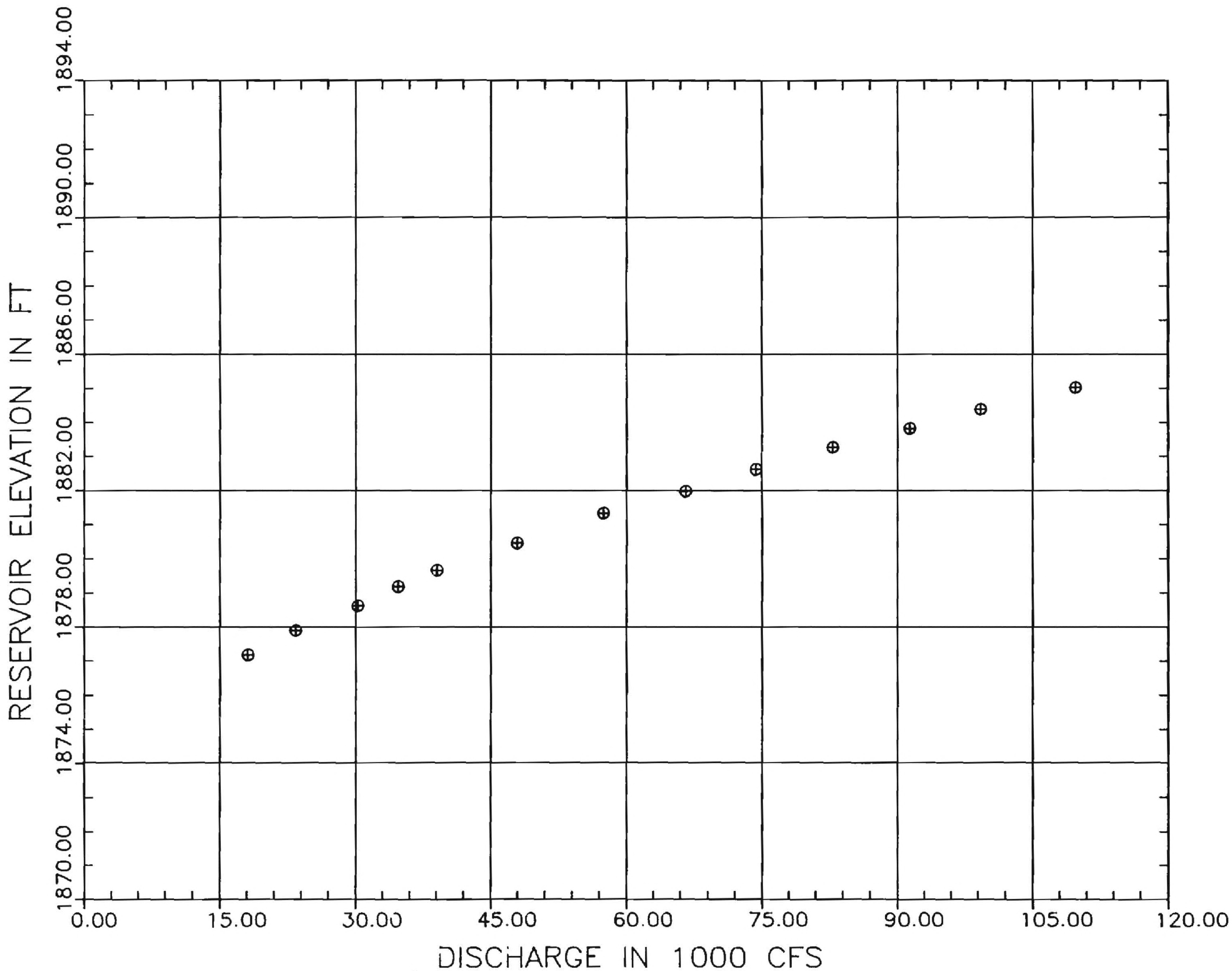


Figure 2. Rating curve for Burton Dam with spillway blocked

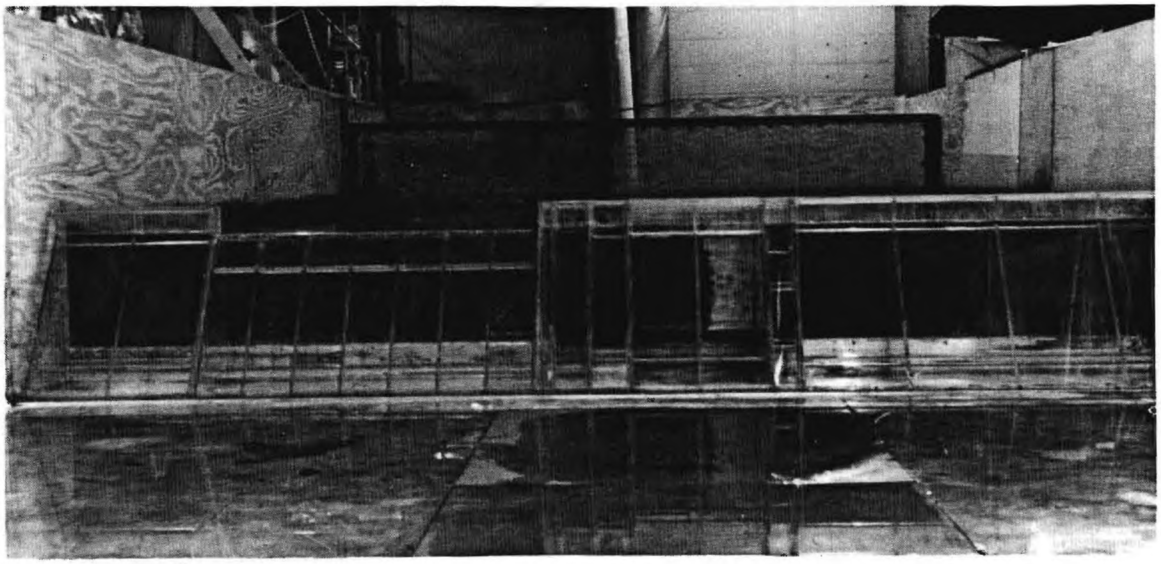


Figure 3 Photograph of Nacoochee Model in 14-ft wide flume

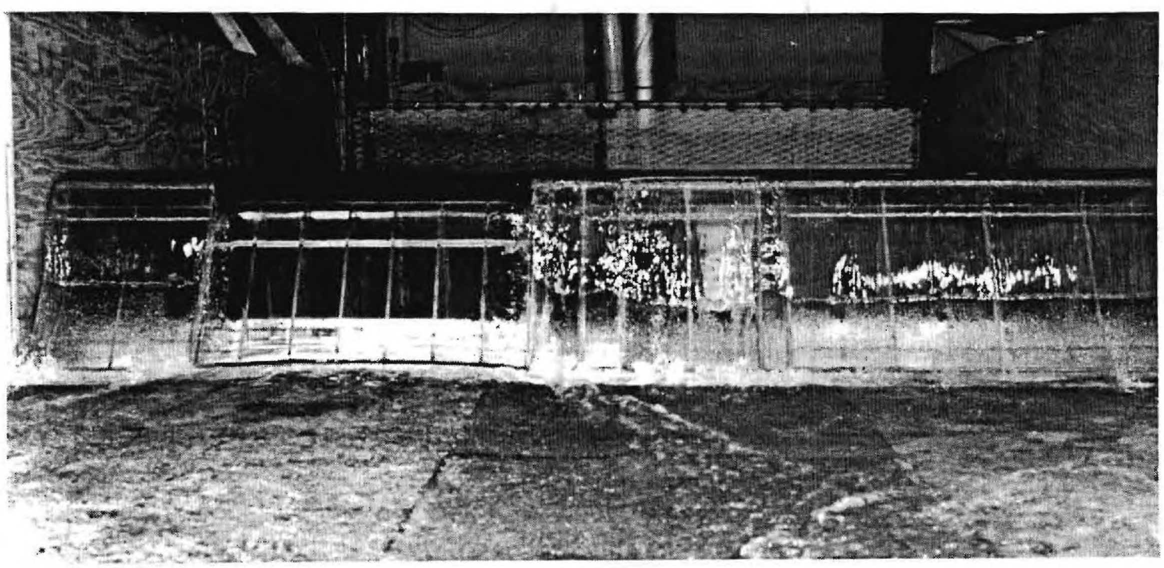


Figure 4 View of Nacoochee Model in operation

of 40 to 1 could be accommodated for the relatively small dam length of 490 ft. This model, consisting of a top crest width of 12.25 ft, was constructed exclusively of Plexiglass and placed in the 14-ft wide flume, as shown by the photograph of the completed model in Figure 3. The floor of the flume corresponded to an elevation of 1690.0 ft, and the crest of the dam was constructed at elevation 1765.0 ft, 12.5 ft above the crest of the spillway, which was at elevation 1752.5 ft. Considerable care was exercised to ensure that the two crests were very level as well as being precisely 12.5 ft different in elevation. The photograph in Figure 4 shows the model in operation with water flowing over spillway and the non-overflow sections.

Tests were initially conducted without the approach topography in place and no powerhouse extension. Later tests conducted with gravel in place to represent topography corresponding to map contours, and the inclusion of a powerhouse extension indicated no measurable difference except for flows exceeding 50,000 cfs. For that reason, only results for the approach topography in place will be included in this report for flows less than 44,000 cfs. Figure 5 shows the rating curve for Nacoochee Spillway and Dam up to the maximum possible laboratory flow. Figure 6 shows flow over the spillway alone at a rate of 20,000 cfs. Water overtops the dam crest (elevation 1765.0 ft) at approximately 28,000 cfs. Figures 7 and 8 show the flow going over the spillway and non-overflow sections at discharges of 35,000 cfs and 55,000 cfs, respectively. Figure 9 provides a view of the overflow pattern from below the dam at a much higher rate.

The placement of a vertical barrier behind the spillway itself yields information on the flow characteristics of the crest of the dam, albeit the effects of flow contraction at the barrier ends. The results of such a test are shown in Figure 10. The interpretation of these data and others will be explained later in this report.

TALLULAH FALLS DAM

A sectional model was constructed of the Tallulah Falls Spillway and Dam inasmuch as the entire structure was comprised of spillway and piers. The 32-ft spacing between pier centerlines allowed for a three-bay model to be conveniently constructed in the 3-ft wide flume at a scale ratio of 32. The floor of the 3-ft high glass-walled flume correspond to an elevation of 1430.0 ft, a level corresponding to the average ground level at the heel of the dam. The crest was at elevation 1493.0 ft and the top of the bridge at elevation 1517.33 ft. The width between respective piers was 28.0 ft. At the sidewalls of the flume only one half of the 4.0 ft pier width was constructed to create symmetric flow. A view of the sectional model of the Tallulah Falls Spillway and Dam is shown in Figure 11.

The rating curve for Tallulah Falls Spillway and Dam is plotted in Figure 12. Photographs of the

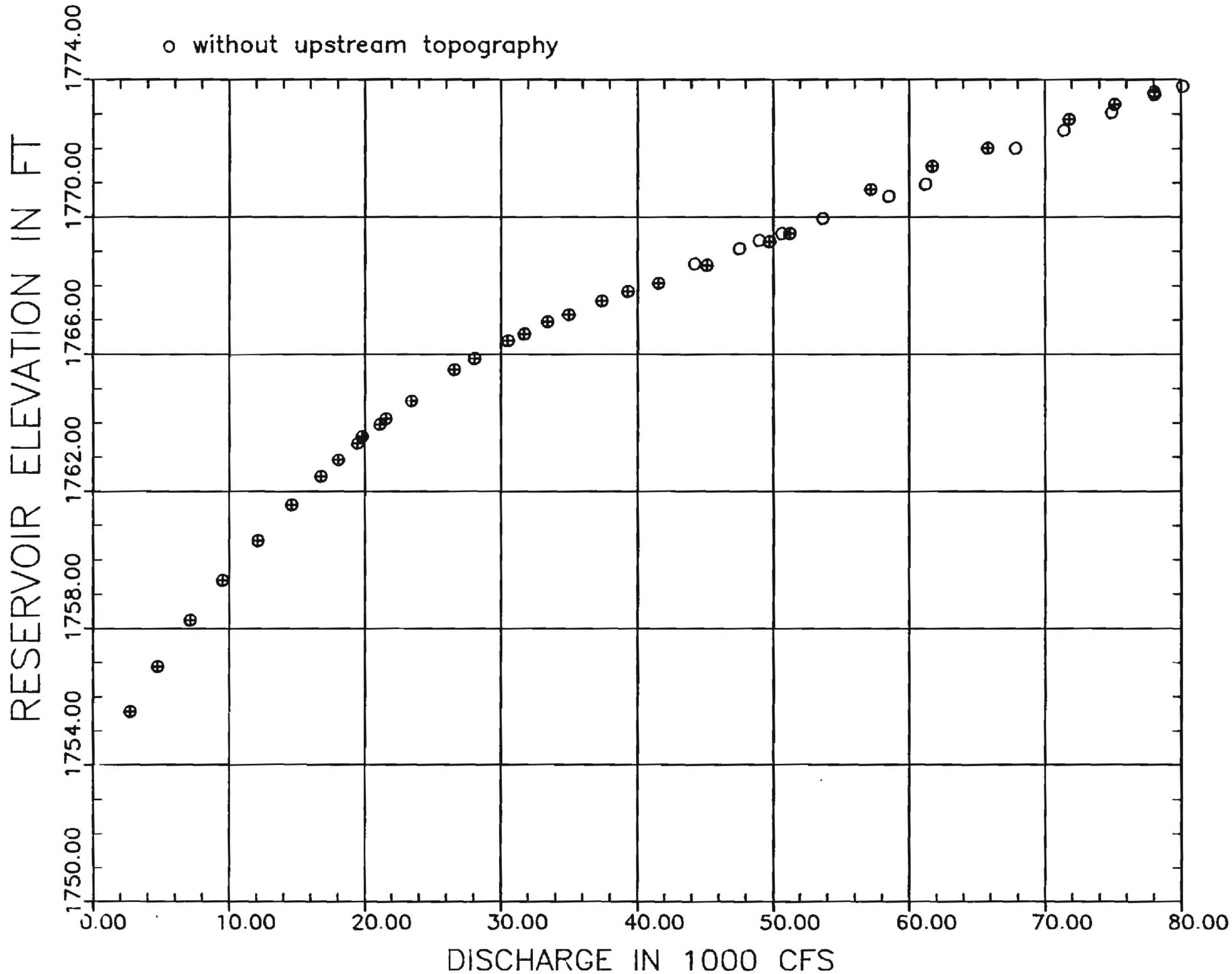


Figure 5. Rating curve for Nacoochee Spillway and Dam

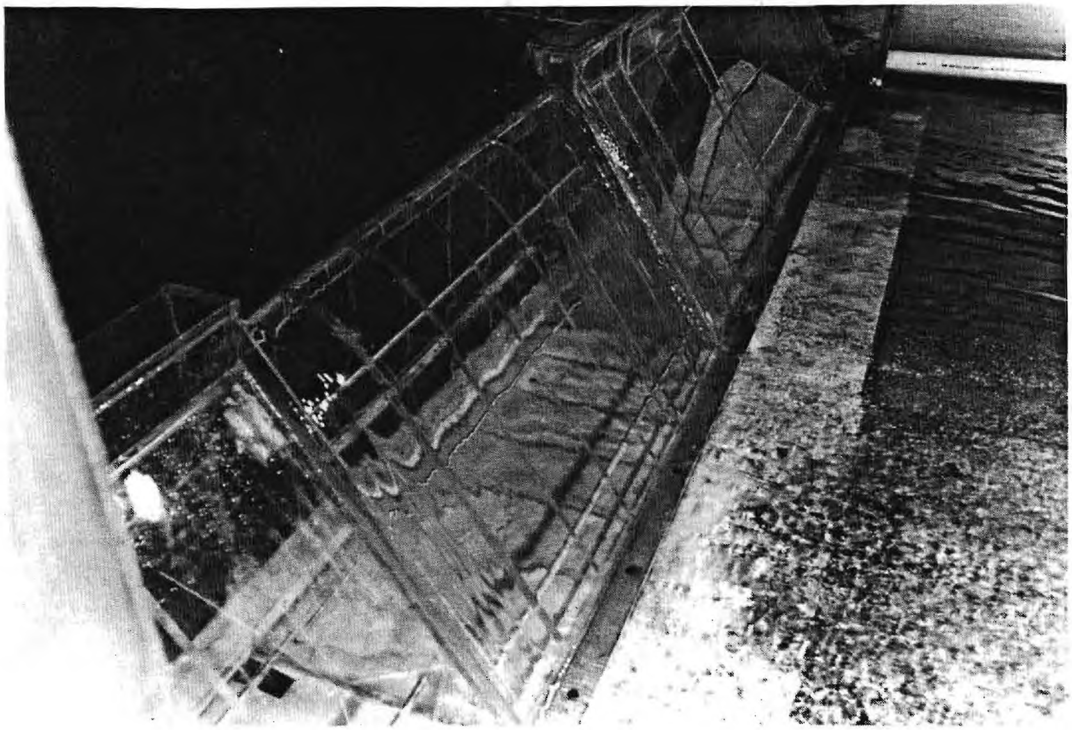


Figure 6 Flow over Nacoochee Spillway alone (Q=20,000 cfs)

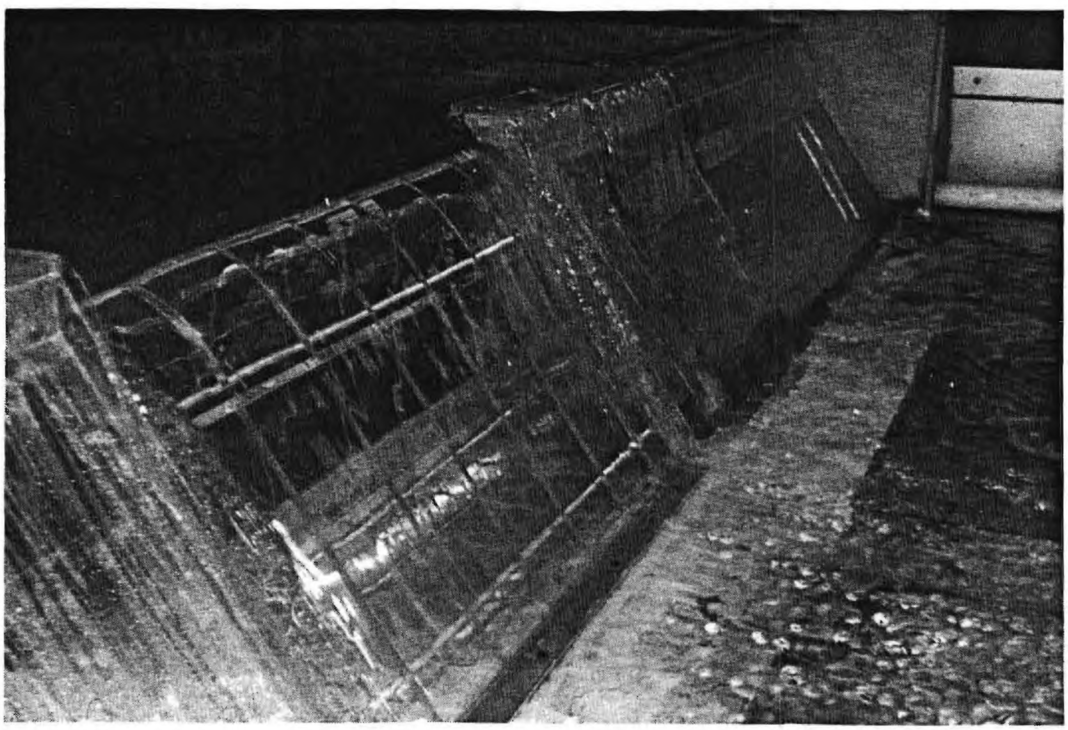


Figure 7 Flow over Nacoochee Spillway and Dam (Q=35,000 cfs)

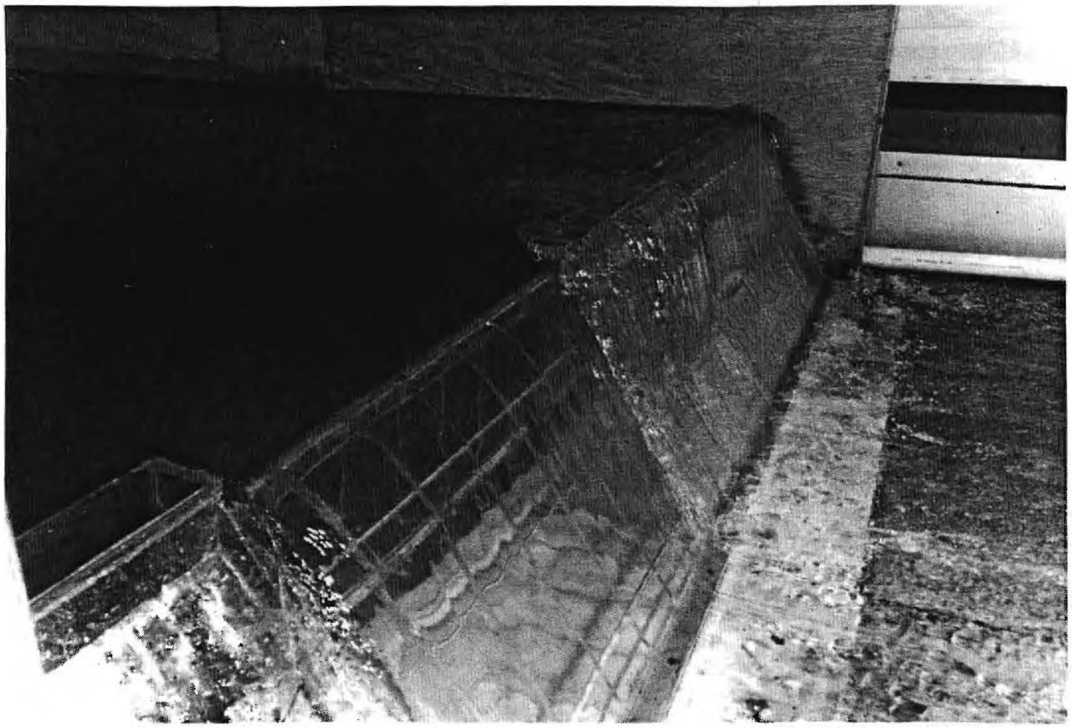


Figure 8 Flow over Nacoochee Spillway and Dam (Q=55,000 cfs)

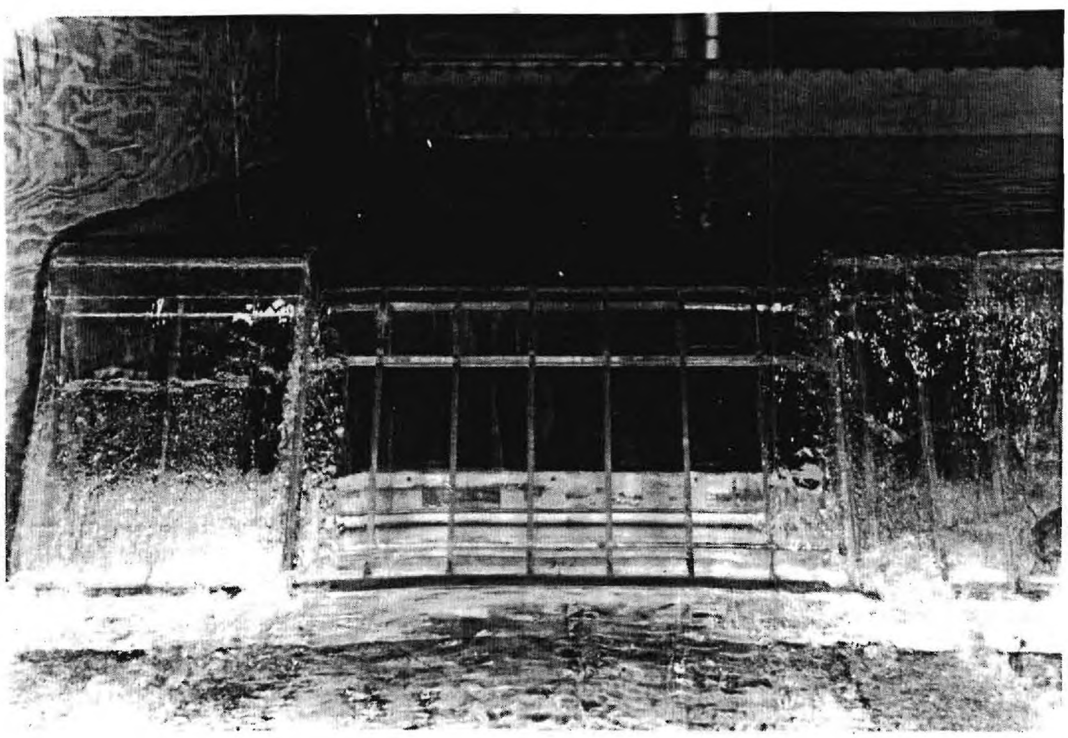


Figure 9 View of Very High Flow over Nacoochee Spillway and Dam

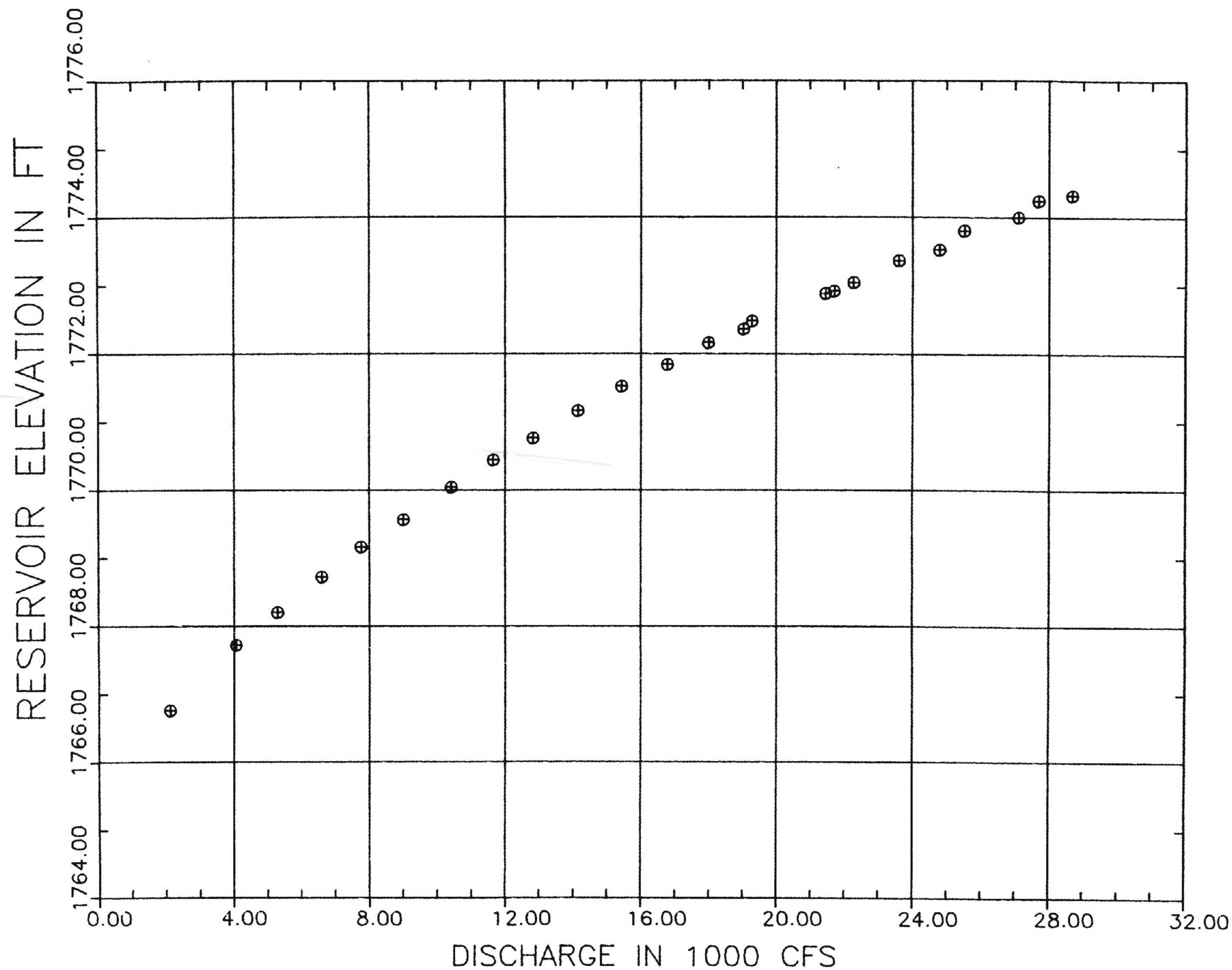


Figure 10. Rating curve for Nacoochee Dam with spillway blocked

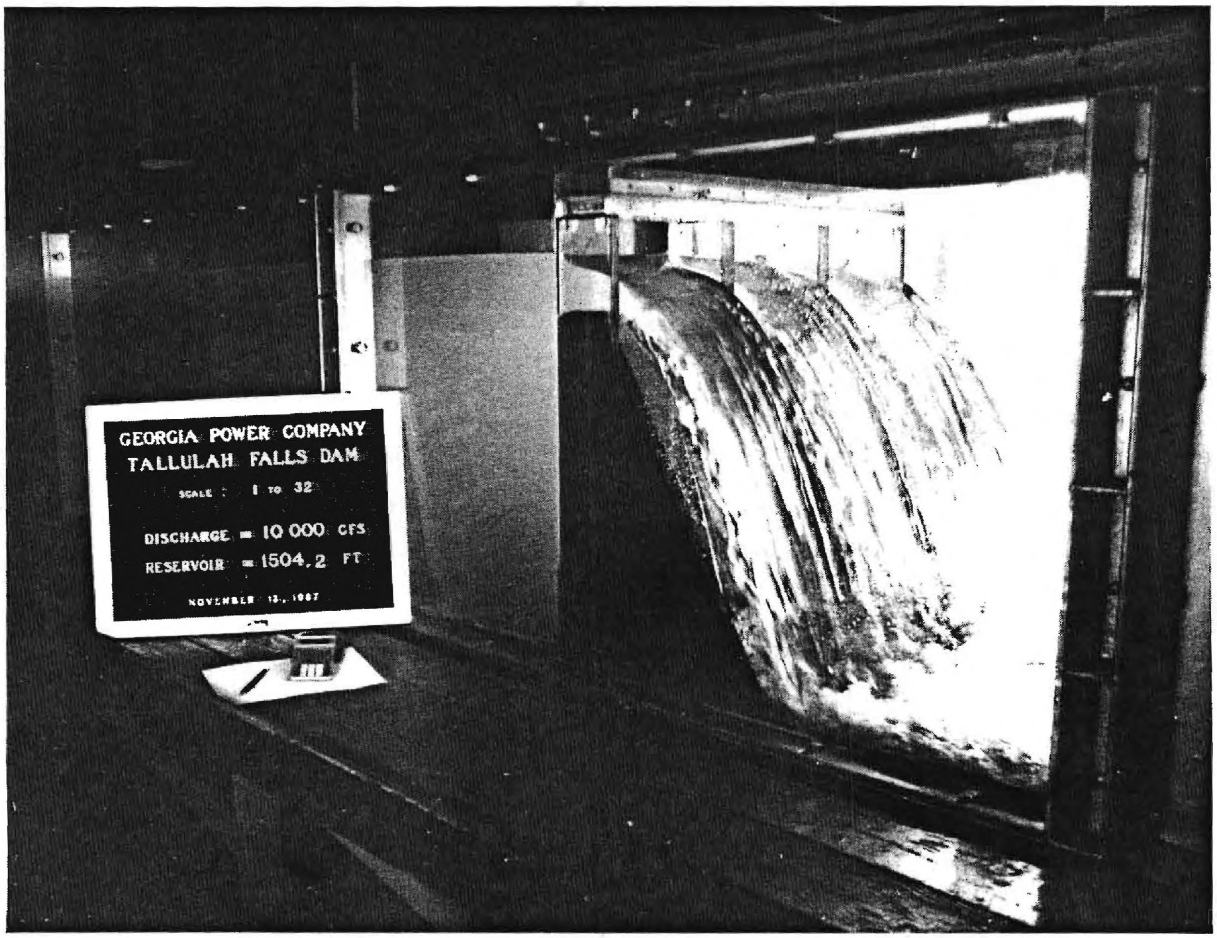


Figure 11 View of Tallulah Falls spillway in Operation

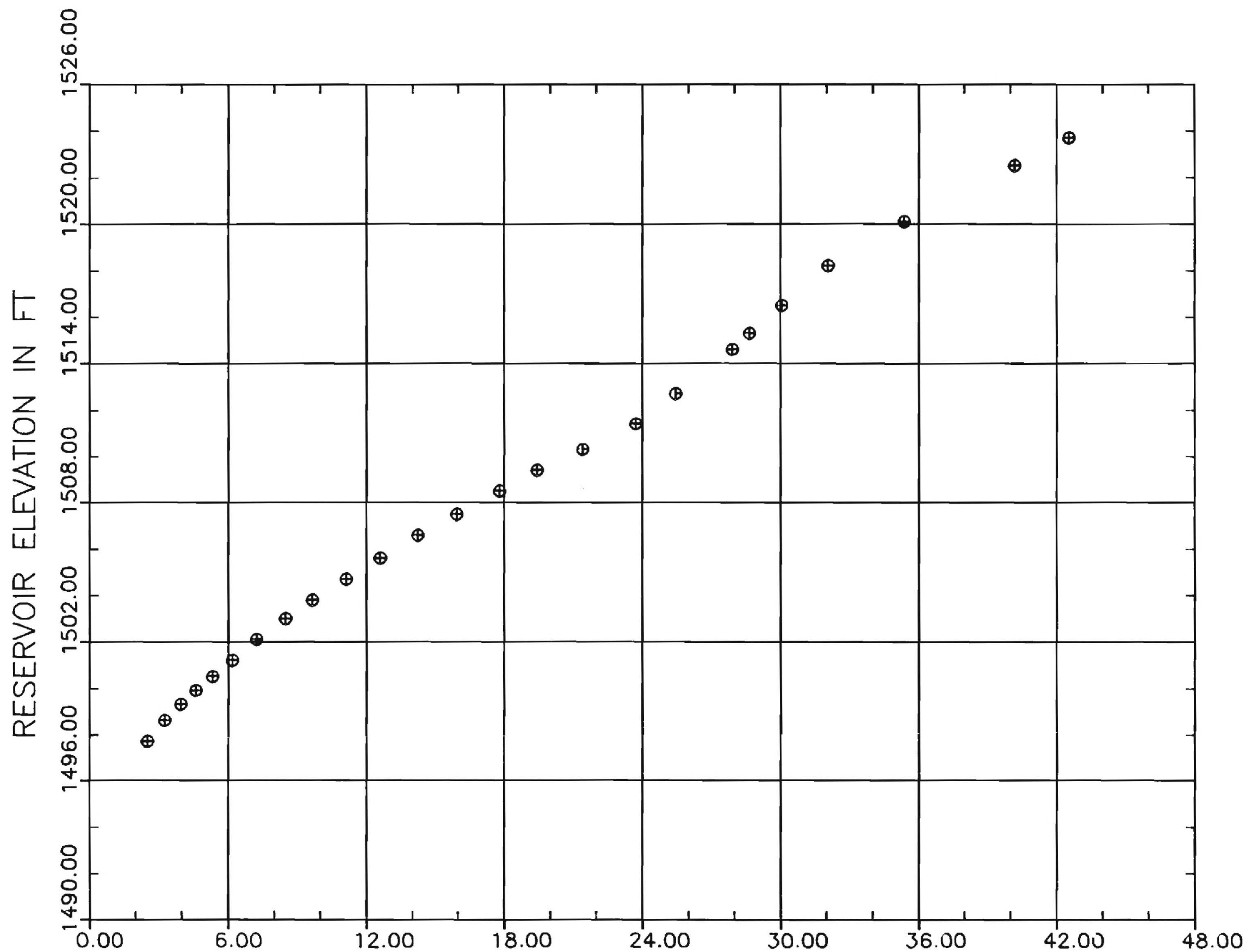


Figure 12. Rating curve for Tallulah Falls Spillway

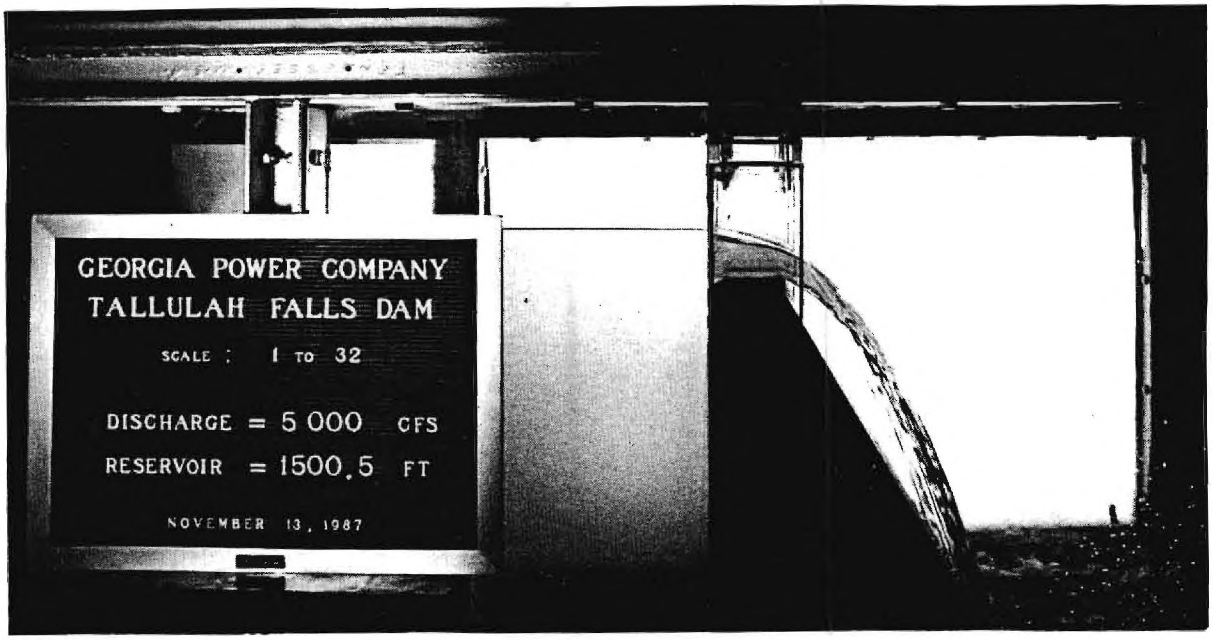


Figure 13 Flow of 5,000 cfs over Tallulah Falls Spillway

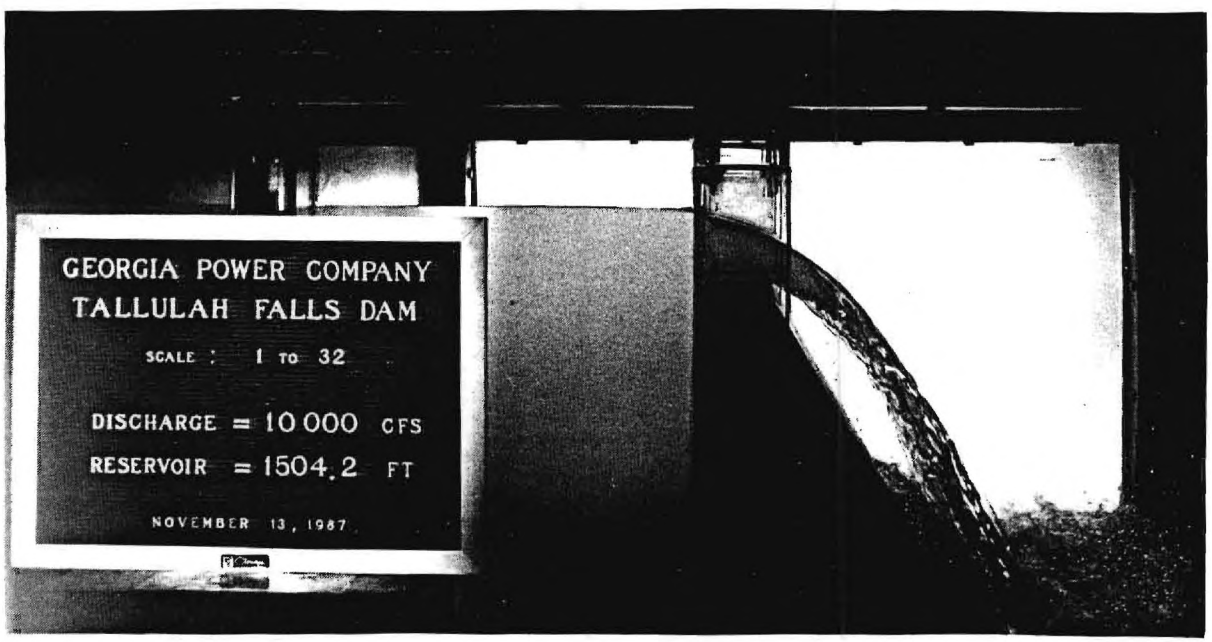


Figure 14 Flow of 10,000 cfs over Tallulah Falls Spillway

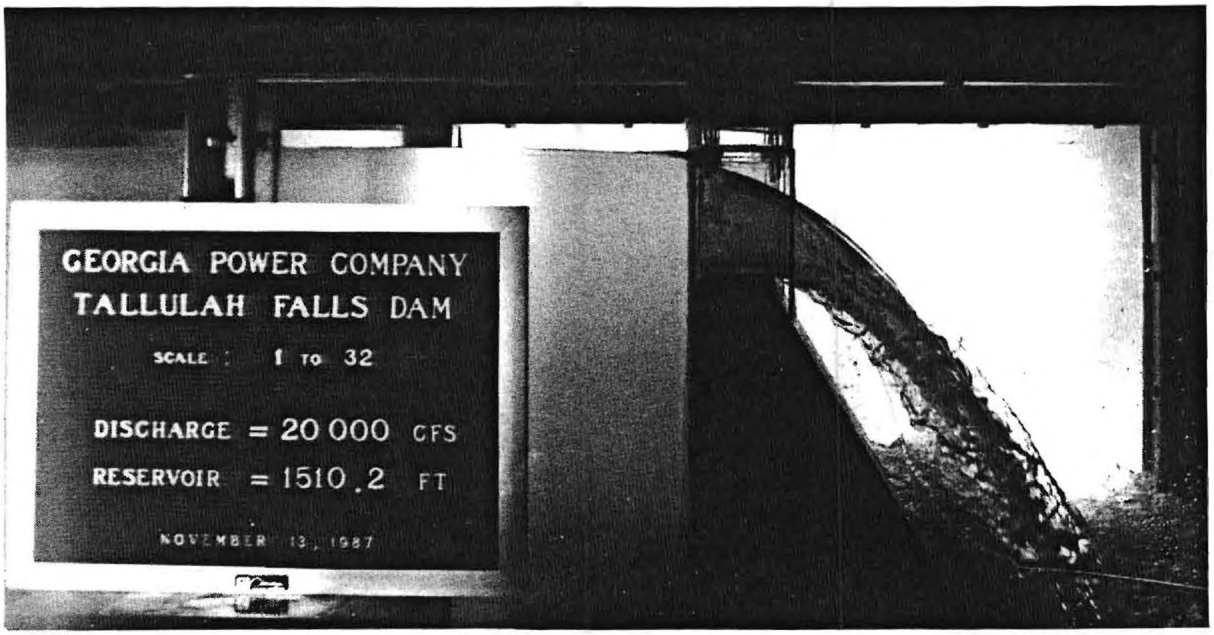


Figure 15 Flow of 20,000 cfs over Tallulah Falls Spillway

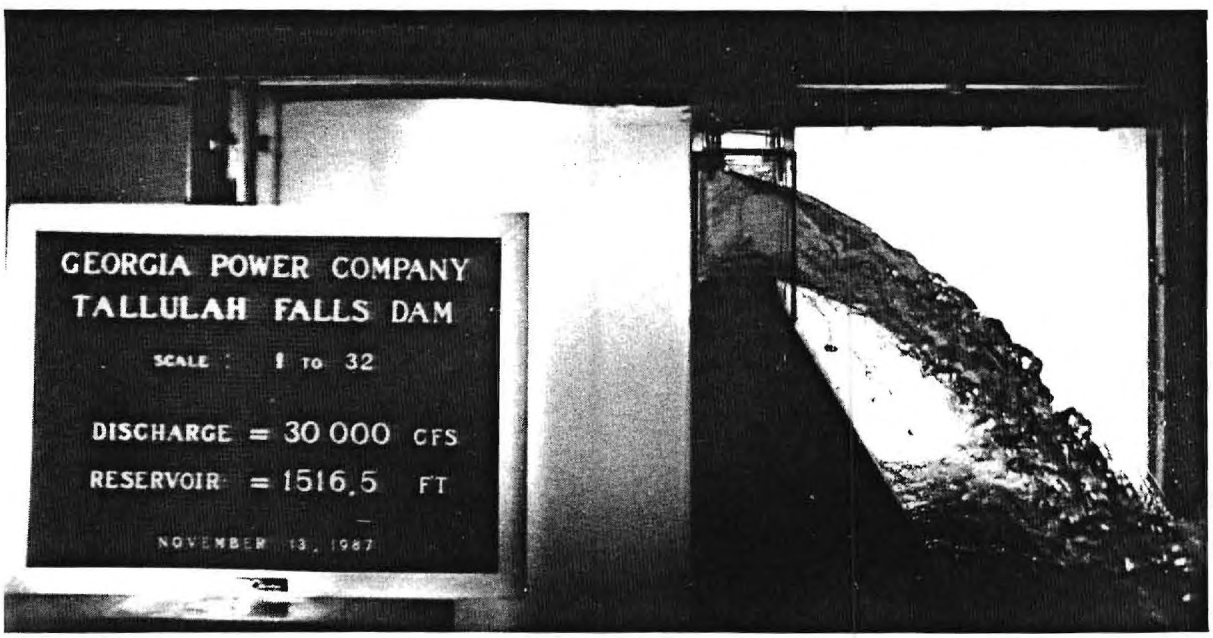


Figure 16 Flow of 30,000 cfs over Tallulah Falls Spillway

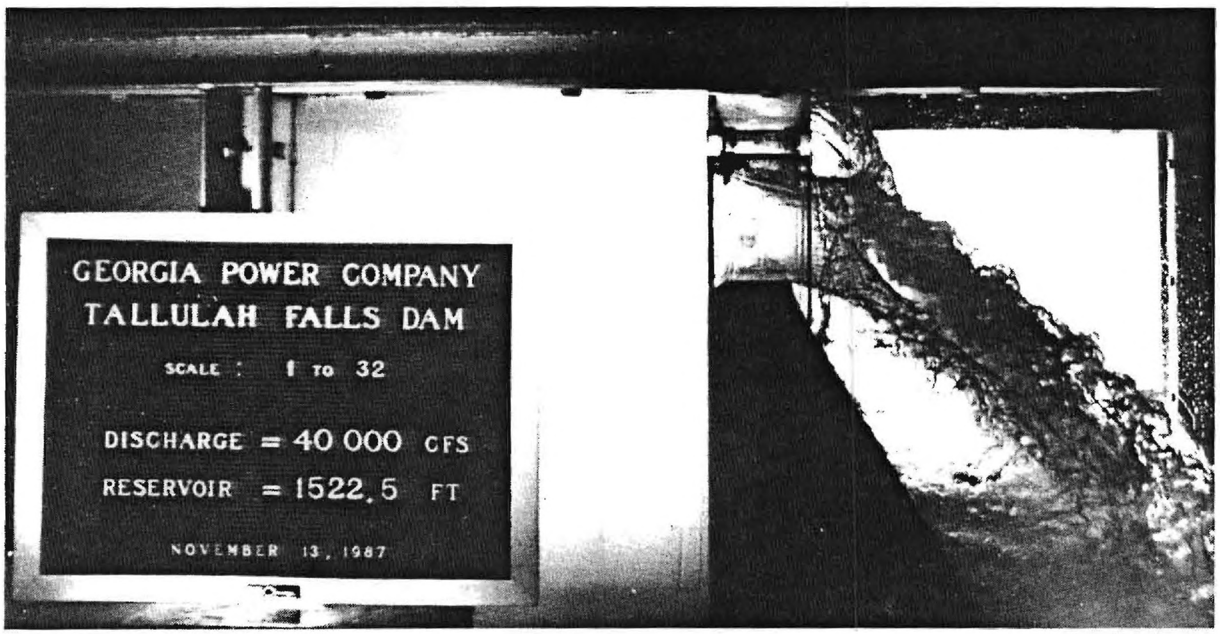


Figure 17 Flow of 40,000 cfs over Tallulah Falls Spillway and Bridge

various flow conditions and nappe profiles are shown by the photographs in Figures 13-17 for flows of 5,000, 10,000, 20,000, 30,000, and 40,000 cfs, respectively. The first three nappe profiles (Figures 13-15) indicate weir flows prior to the water touching the lower part of the bridge, which is at elevation 1510.8 ft. At a reservoir elevation of 1511.4 ft, corresponding to a discharge of 23,700 cfs, the water just impinged on the lower surface of the bridge floor. Between this flow and the flow of 32,100 cfs at which magnitude the water began to pass over the top of the bridge, the flow can be called an orifice-type flow. Figure 16 shows an orifice-type flow for a discharge of 30,000 cfs. Figure 17 illustrates the flow pattern at 40,000 cfs for flow going both though the space and over the bridge.

TUGALO DAM

The Tugalo Dam, being the highest of all four (160 ft) and the farthest downstream and hence having the greatest discharge, placed constraints on model size and scale. In order to investigate a three-bay structure, which consisted of a 75.0 ft width, flow limitations required that a scale ratio of 37.5 be selected. This meant that the flume walls had to be narrowed to 2.0 ft, corresponding to the 75.0 ft for the three bays. The spacing between piers is 22.0 ft for Tugalo. For this model scale the 3-ft high glass walls of the flume limited the height of the dam as well. An initial investigation was conducted for the floor of the flume at elevation 830.0 ft, 85 ft above the actual level of 745.0 ft. Concern regarding the effect of the height of dam led to placing temporary walls in the flume to allow for raising the spillway and dam such that the entire section could be tested. In this case the floor of the flume corresponded to elevation 830.0 ft.

Figure 18 shows the shorter Tugalo model in place in the 3-ft glass-walled flume. The elevations of the crest of the spillway and dam are 885.0 and 905.0 ft, respectively. The elevation of the lower floor of the bridge is 902.0 ft. The comprehensive rating curve for the shorter model with and without the bridge in place is shown on Figure 19. Corresponding photographs for six discharges, ranging from 10,000 cfs to 60,000 cfs, are shown in Figures 20-25, respectively. The structure performs as a weir for the first two flows -- 10,000 cfs (Figure 20) and 20,000 cfs (Figure 21). At an elevation of 905.9 ft , at which the flow is 23,000 cfs, water just touches the lower part of the bridge. At a discharge of 26,200 cfs (elevation 907.9) water begins to pass over the top of the bridge as well. Through and over flows are seen in Figures 22 and 23, corresponding to discharges of 30,000 cfs and 40,000 cfs, respectively. Actually, at 41,000 cfs (elevation 913.5) the aeration shown in Figures 20-23 begins to disappear inasmuch as the increasing amount of flow passing over the top of the bridge begins to inhibit the aeration caused by the spillway piers. Figures 24 and 25 show the non-aerated flow on the spillway slope itself for flows of 50,000 cfs and 60,000 cfs, respectively. The change in the aeration

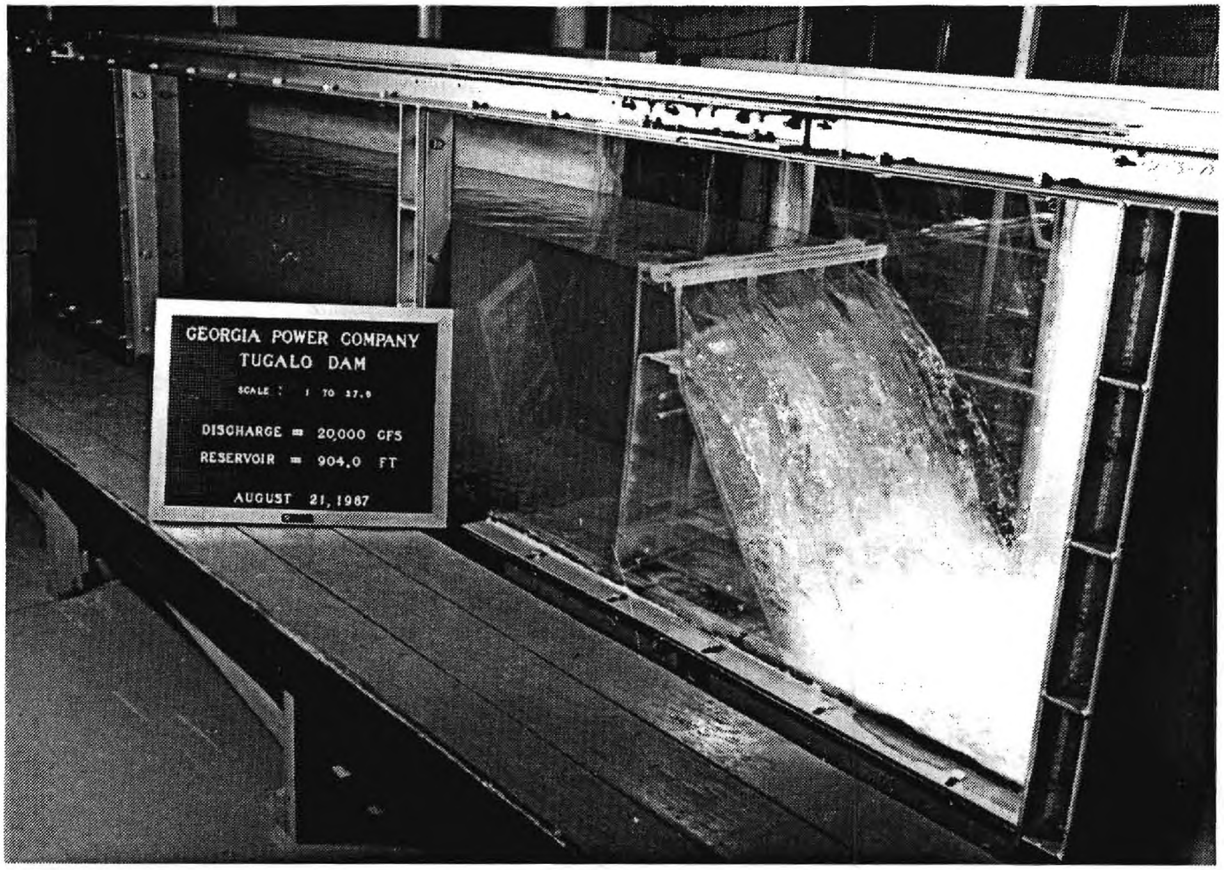


Figure 18 View of Tugalo Spillway in operation

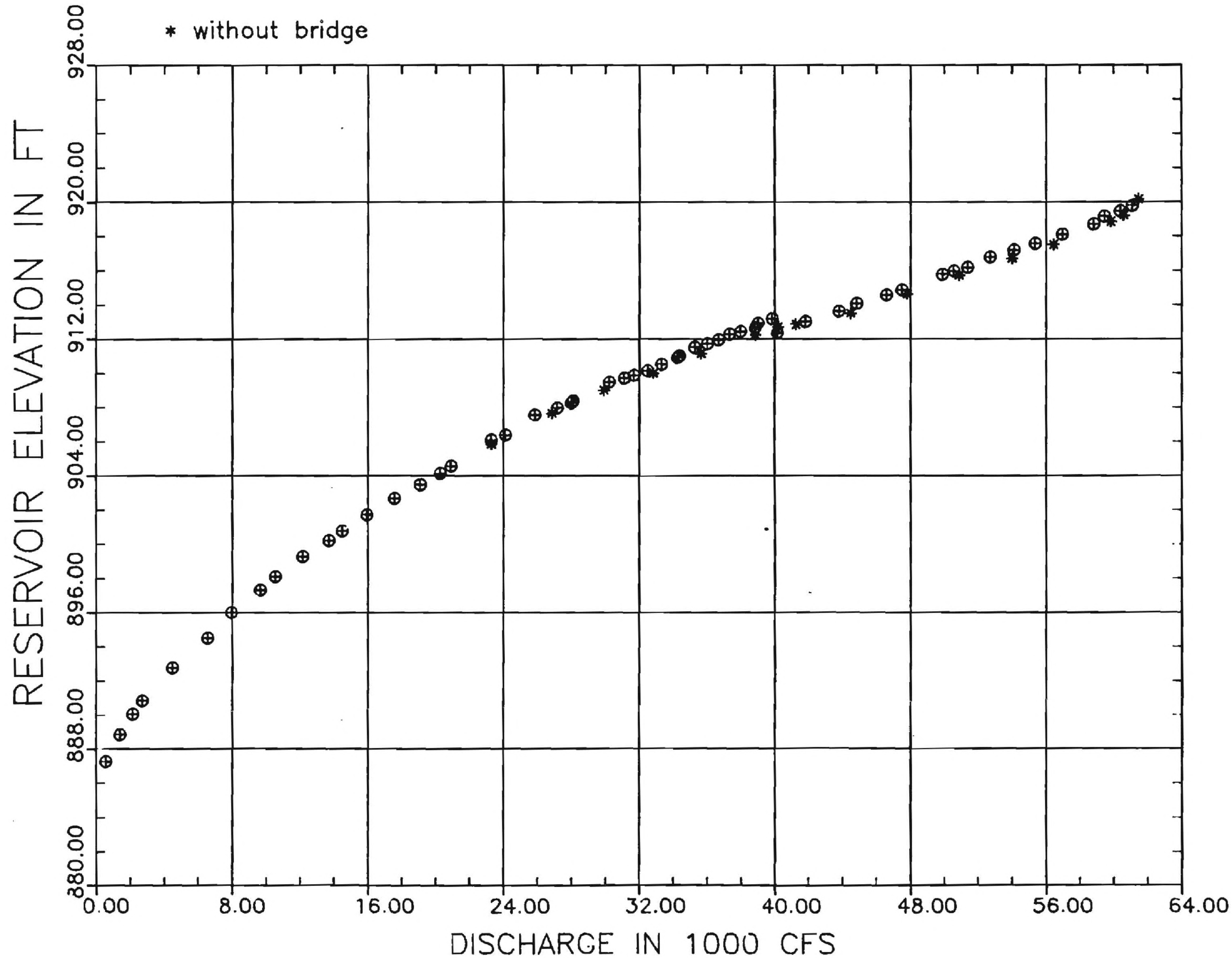


Figure 19. Rating curve for Tugalo Spillway and dam

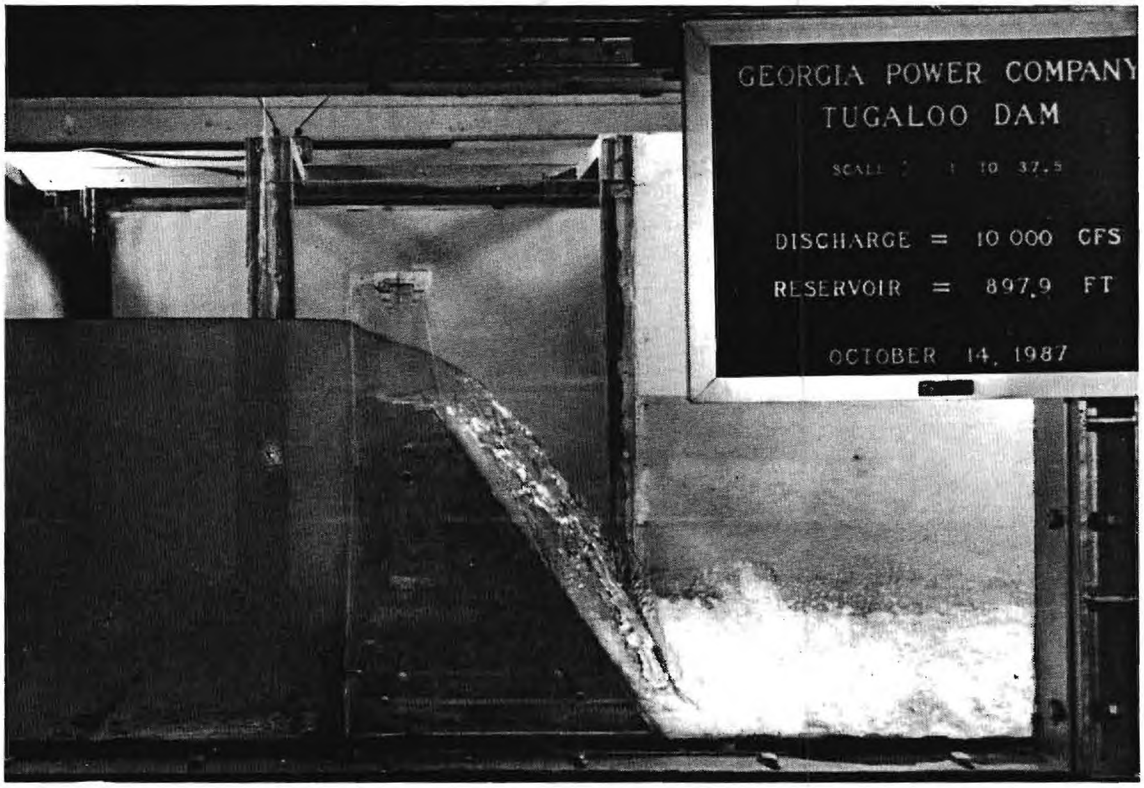


Figure 20 Flow of 10,000 cfs over Tugalo Spillway

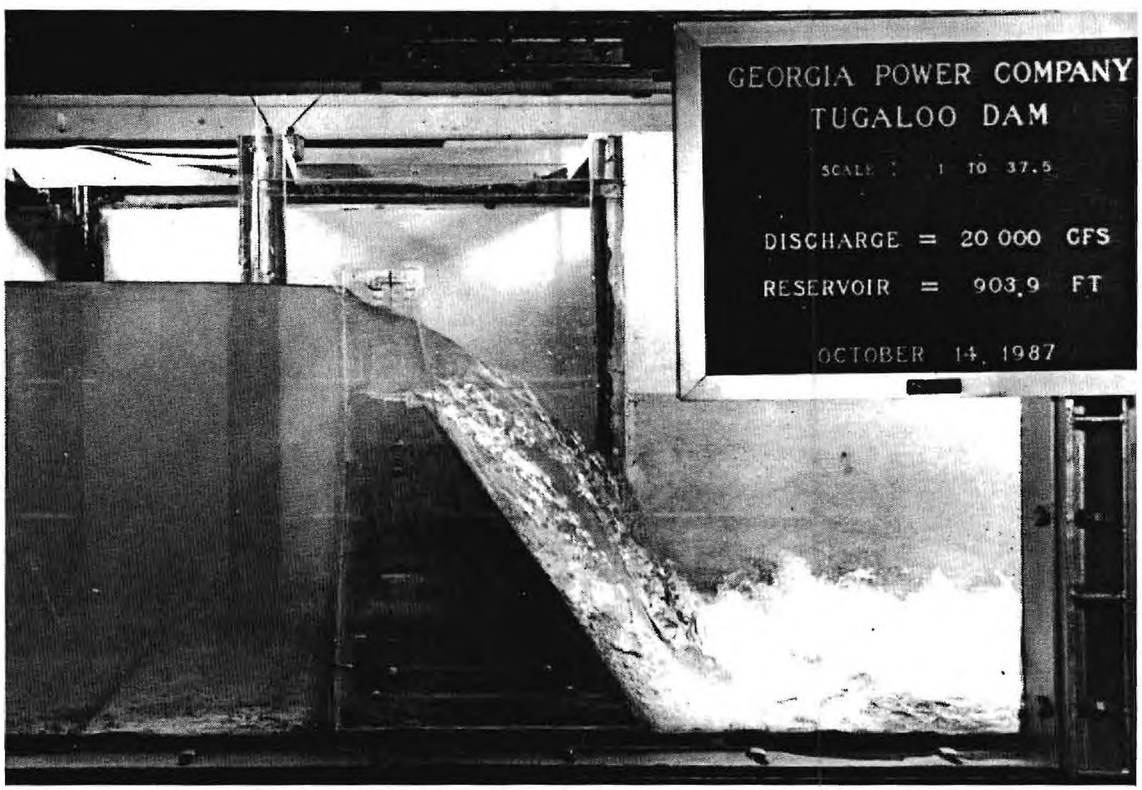


Figure 21 Flow of 20,000 cfs over Tugalo Spillway

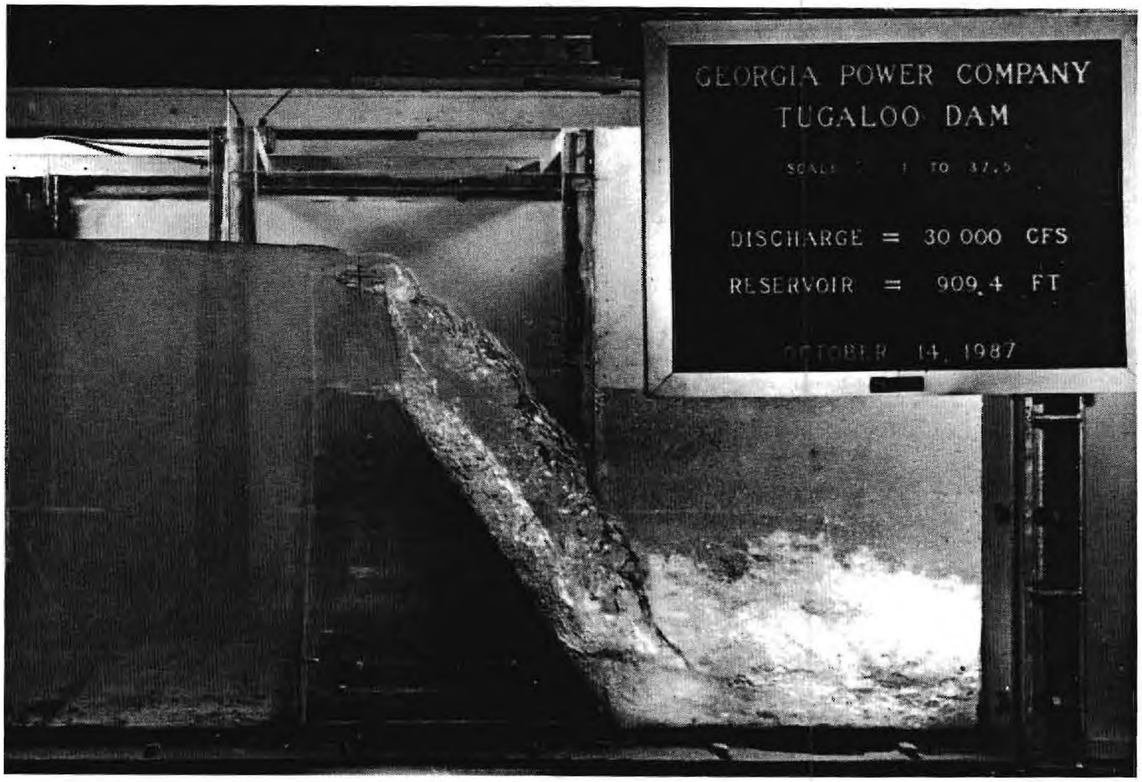


Figure 22 Flow of 30,000 cfs over Tugalo Spillway and Bridge

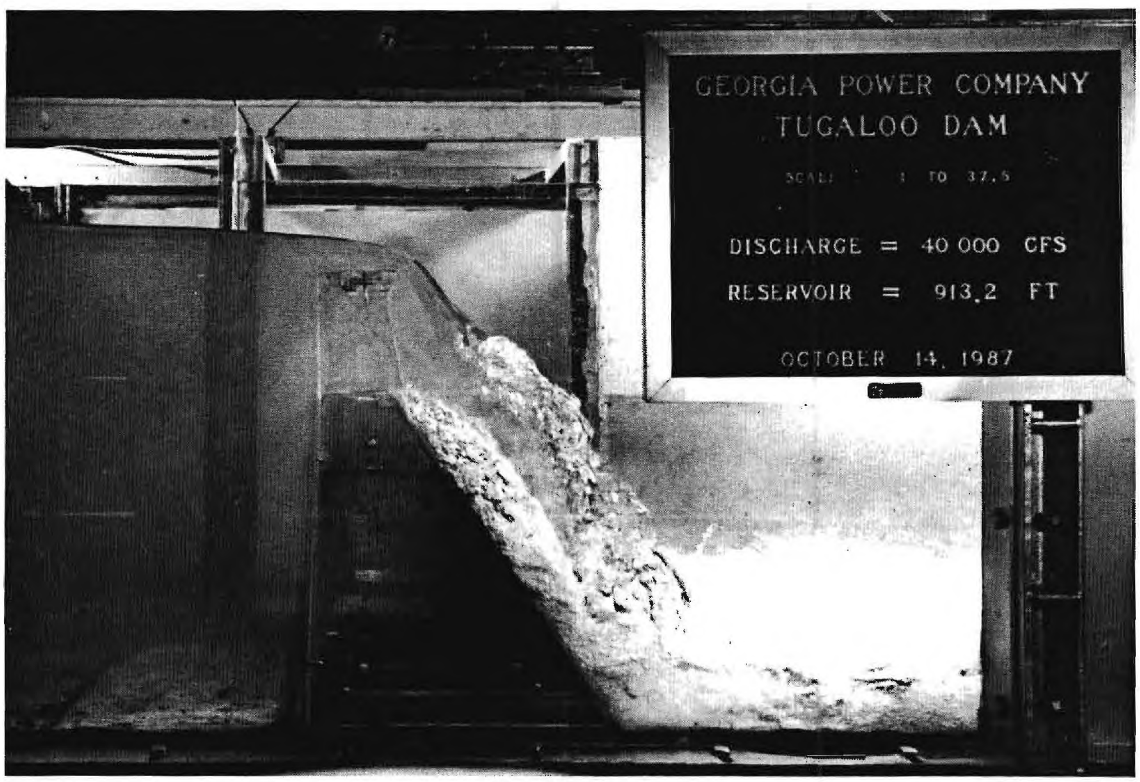


Figure 23 Flow of 40,000 cfs over Tugalo Spillway and Bridge

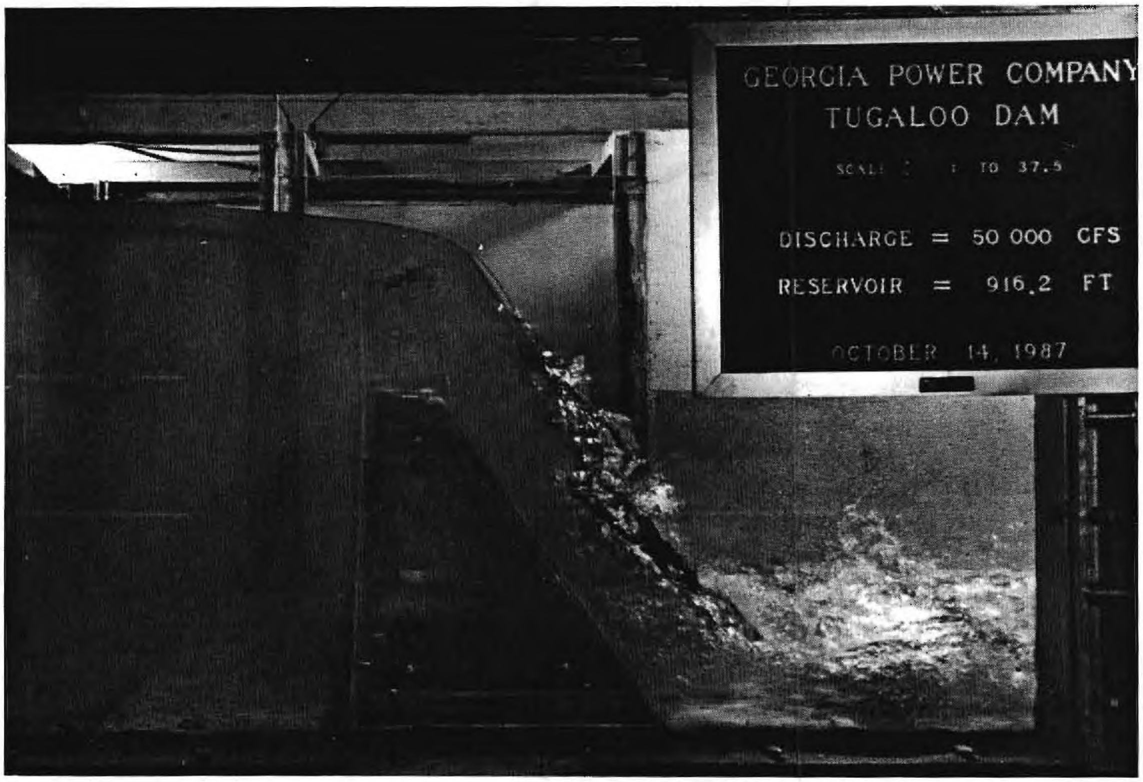


Figure 24 Flow of 50,000 cfs over Tugalo Spillway and Bridge

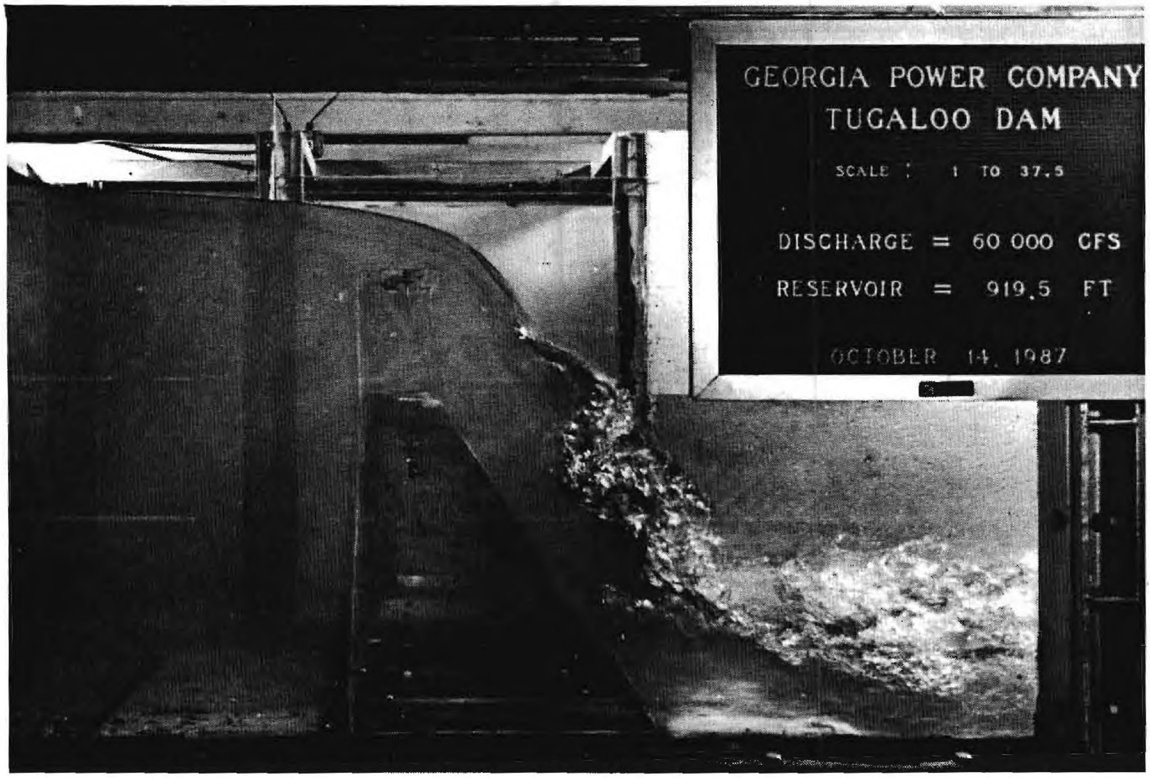
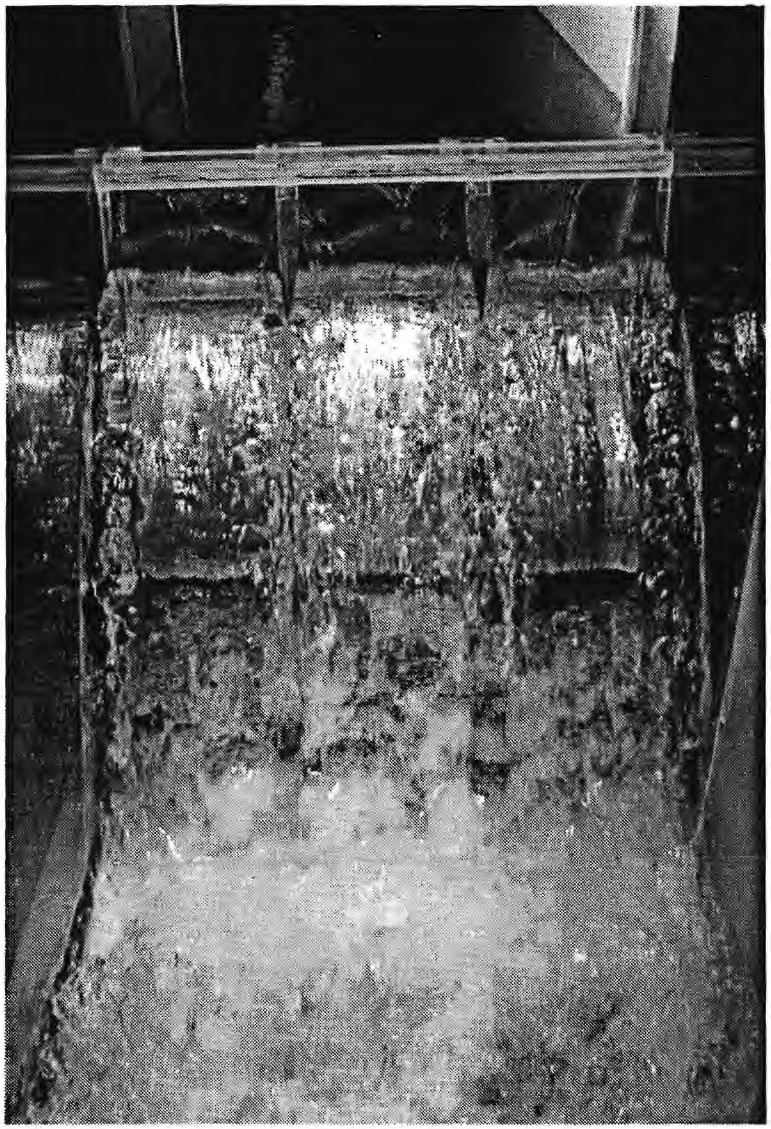


Figure 25 Flow of 60,000 cfs over Tugalo Spillway and Bridge



View of Pier Aeration for Tugalo Spillway for Flow under Bridge

Figure 26

View of no Pier Aeration for Tugalo Spillway for Flow over Bridge

Figure 27

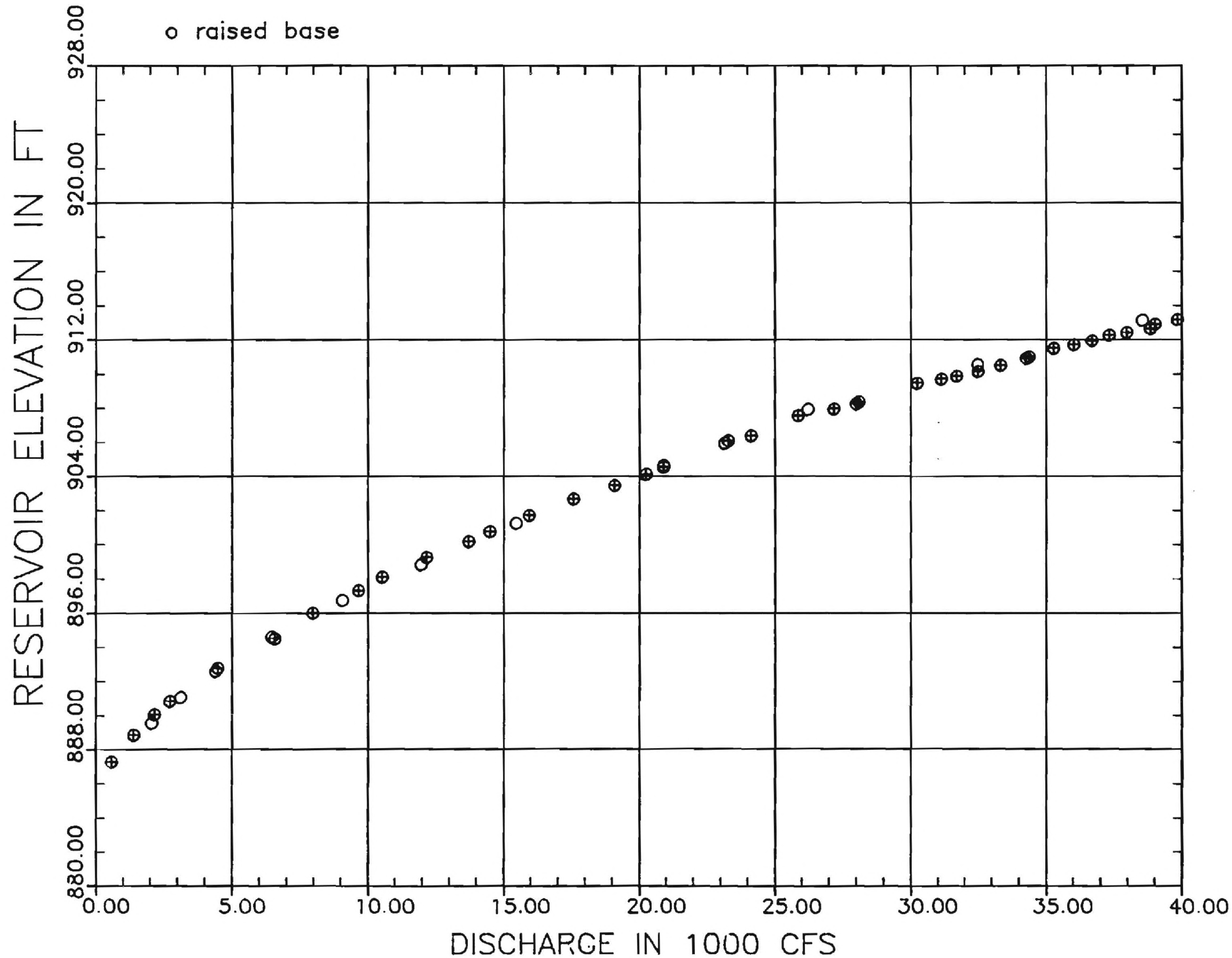


Figure 28. Rating curve for Tugalo Spillway and dam with raised base

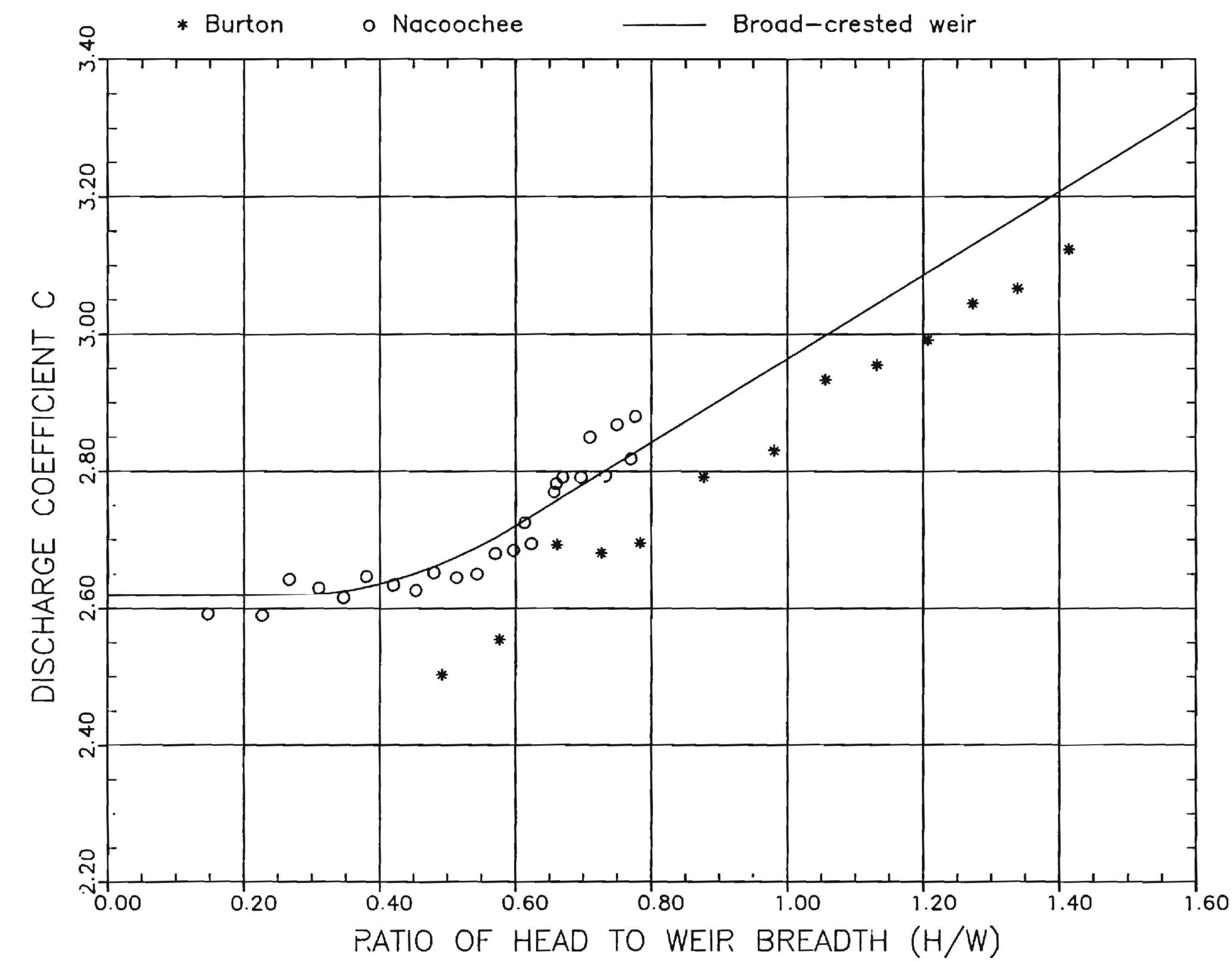


Figure 29. Flow coefficient for Burton and Nacoochee dams with spillways blocked

pattern is apparent by comparing the free surface for flow under the bridge (Figure 26) with that for flow over the bridge (Figure 27).

In order to ascertain any effect of the height of dam on the flow capacity of the structure the side walls of the flume were raised by installing plywood sides. The same Plexiglass model was placed in the flume on top of a scaled portion of the dam to establish the floor of the flume at the proper elevation of 745.0 ft. The results of the raising of the dam are shown in Figure 28. For purposes of comparison, values were taken from Figure 19 for the case of the bridge installed. As can be seen, the effect of the height of the dam is insignificant.

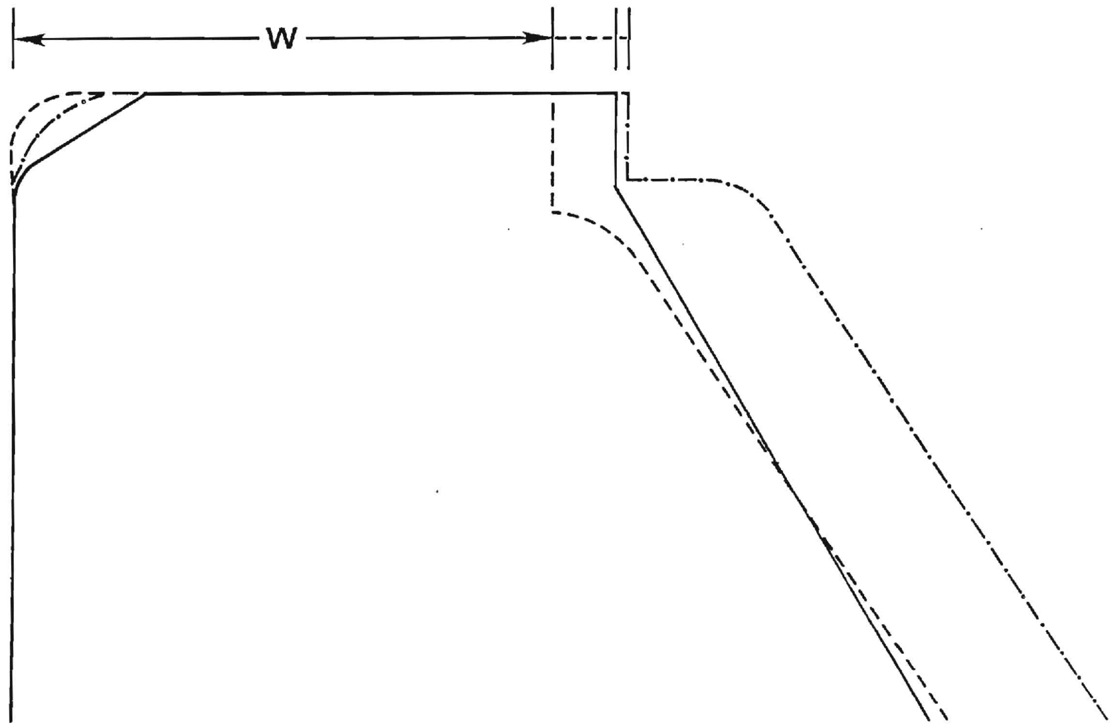
DISCUSSION OF RESULTS

The issue of scaling, especially with regard to the large scale ratio of 80 for the Burton model, can be addressed, and the model data justified to a certain extent by comparing the data for the Burton (and Nacoochee) Dams when the spillways were blocked. The Burton non-overflow section or dam had a uniform cross section and, indeed, the appearance of a broad-crested weir. Except for the minor effect of end contractions at the barrier it would be expected that the Burton dam should behave as a broad-crested weir. With the exception of the powerhouse extension the Nacoochee Dam also has a broad-crested weir shape. For large broad-crested weirs with a sharp upstream corner and a large height of dam to head ratio, the discharge coefficient is defined by

$$Q = CH^{1.5}$$

where C is the discharge coefficient, varying from 2.62 for a very broad weir to much higher values as H/W is increased, in which W is the breadth (width) of the weir. For weirs having a large height to head ratio, Bois [1] reports a correlation of C with H/W. This correlation is plotted in Figure 29 along with the data for Burton and Nacoochee Dams with blocked spillways. The Nacoochee data, for which the model had a scale ratio of 40 and was constructed out of Plexiglass, agrees quite well with the broad-crested weir correlation. As might be expected the Burton data lie slightly below the curve for $H/W > 0.6$, corresponding to a model head greater than 0.7 inch. For smaller model heads the scale effects of surface tension and viscosity appear to be playing a role. The scaling effect for the Burton model is not expected to be serious for the largest flows, for which the model head was probably adequate.

Figure 30 is a composite drawing of the spillway profiles of Burton, Tallulah Falls, and Tugalo Dams, all to the same scale and to the model shape. Each of the three spillways has a broad-crested weir shape and comparable crest breadths. Differences appear at the upstream face and, of course, at



DAM	SYMBOL	CREST ELEVATION	BREADTH (W)
Burton	--------	1860.0	9.2
Tallulah	______	1493.0	10.2
Tugalo	—·—·—	885.0	10.5

Figure 30 Profiles of Spillway Crests for Burton, Tallulah, and Tugalo Dams

the piers. Nevertheless, the data for all three spillways in Figure 31 correlate well and yield somewhat better performance than the broad-crested weir data, included for comparison purposes. The upstream rounding results in better performance than that predicted by a broad-crested weir. It is interesting to note that the data for Burton Spillway correlates well with the other two spillways except for the lowest flow, for which scaling effects are apparent.

For the sectional models for Tallulah Falls and Tugalo Spillways the flow goes from weir to partial orifice control subsequent to the condition of the water striking the under part of the bridge, as seen on Figure 32, which is a plot of all of the data for Tallulah Falls and Tugalo spillways. The relatively short 3-ft high bridge at Tugalo has a minor effect on the discharge coefficient for flow initially under the structure and then, as the reservoir level rises, for combined flow under and over the bridge. In fact, the bridge barely acts as an orifice control, but merely retards the weir-type flow slightly. For the Tallulah Falls Spillway, however, the higher 8.17 ft deep bridge has a dramatic effect on the discharge coefficient once the water level strikes the under side of the structure, as shown by Figure 32. For discharges between 24,000 cfs and 36,000 cfs the flow over Tallulah Falls Spillway is orifice controlled. Of interest is the definition of an orifice-type discharge coefficient. For the Tallulah Falls and Spillway an orifice discharge coefficient is defined

$$Q = C_d A[2gH]^{0.5}$$

in which A is the rectangular area outlined by the piers, spillway crest, and bottom of bridge, C_d is the orifice discharge coefficient, and H is the head referenced to the mid-height between spillway crest and bottom of bridge. For the Tallulah Falls Spillway, Figure 33 illustrates the variation of C_d with flowrate. The head H is referenced to the mid-height between spillway crest and bottom of bridge, corresponding to elevation 1501.4 ft for the Tallulah Falls Spillway. The discharge coefficient C_d ranges between 0.67 and 0.72, approximately -- quite reasonable values for an orifice.

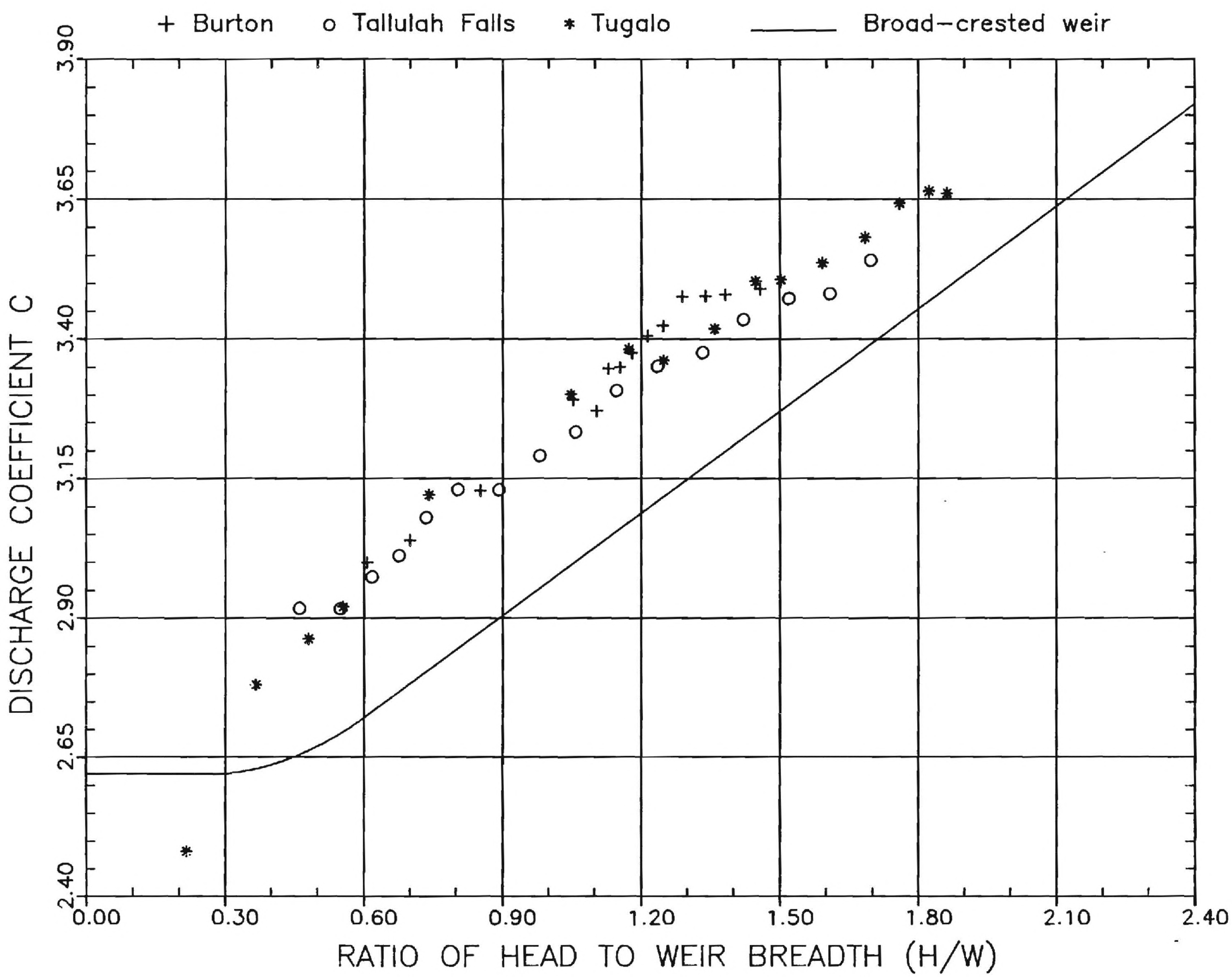


Figure 31. Flow coefficient for Burton, Tallulah, and Tugalo spillways

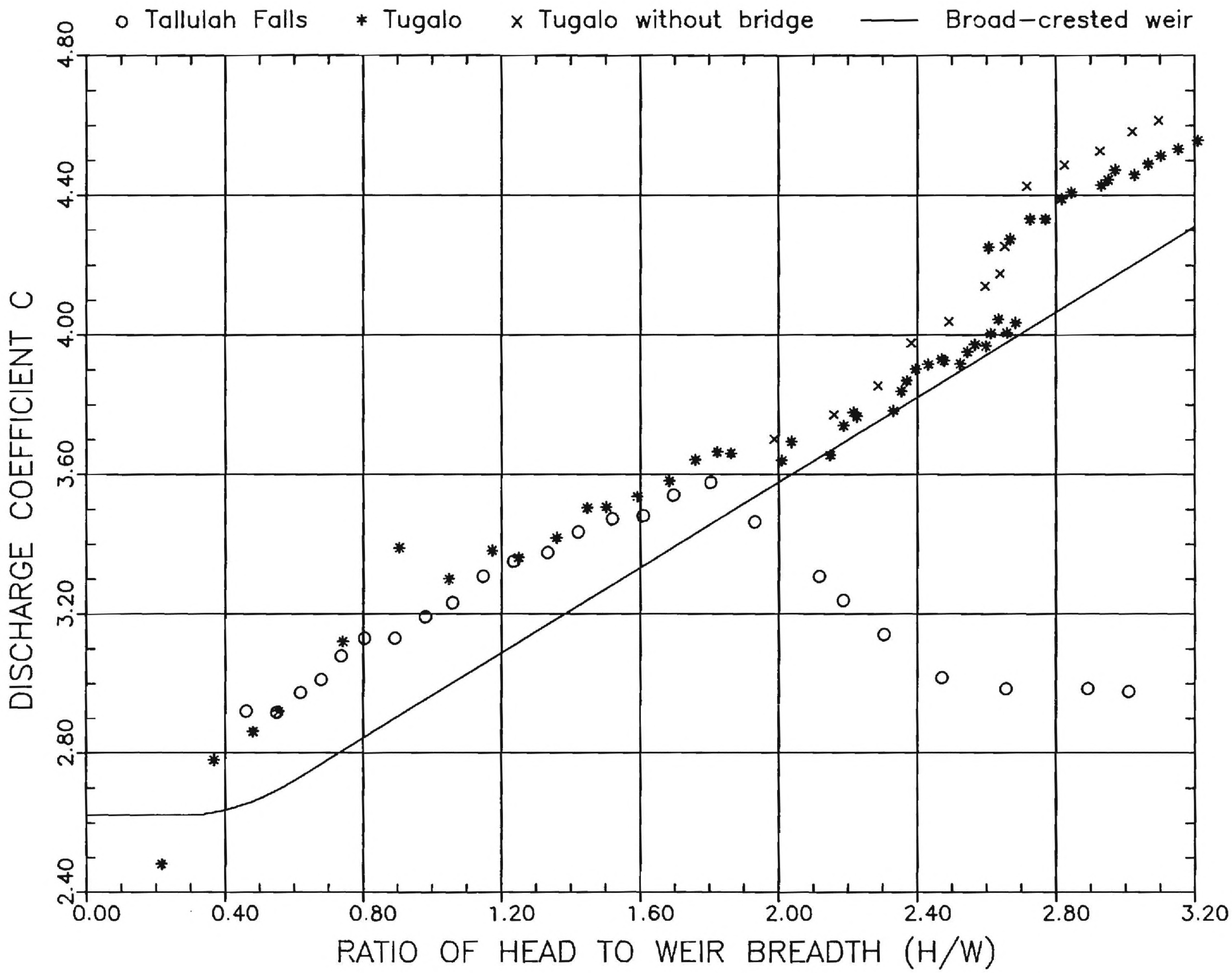


Figure 32. Flow coefficient for Tallulah and Tugalo Spillways illustrating effect of bridges

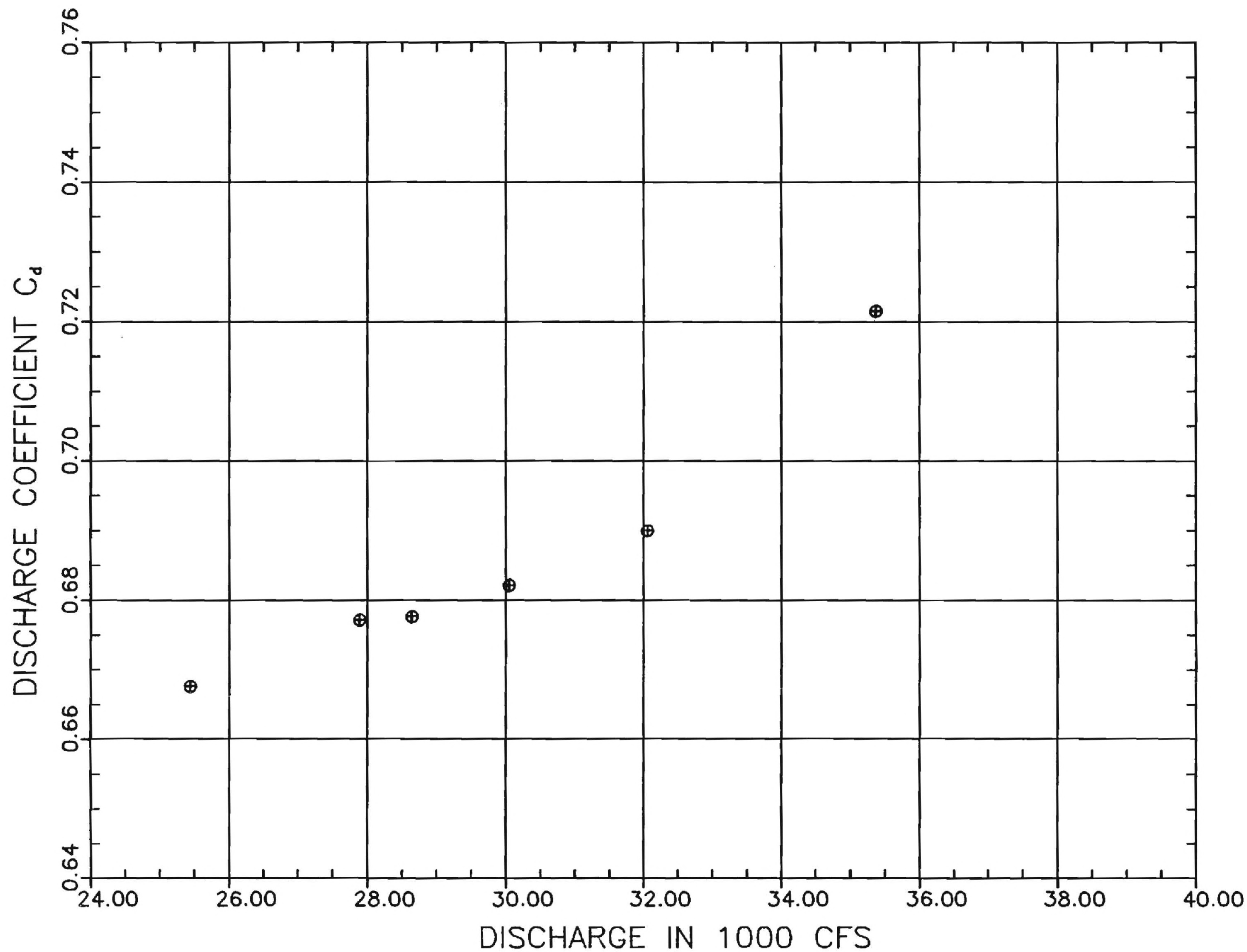


Figure 33. Orifice discharge coefficient for Tallulah Spillway for flow under bridge

REFERENCE

1. Bos, M. G., Discharge Measurement Structures, International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands, 464 pages, 1964.